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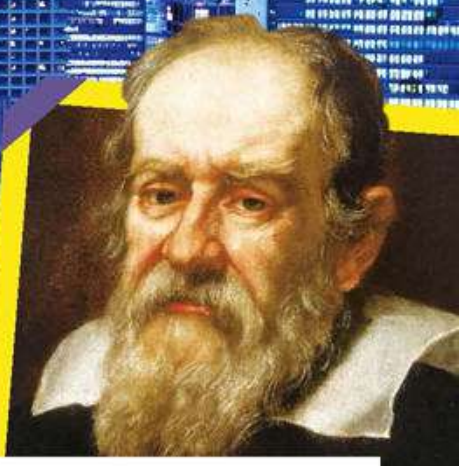
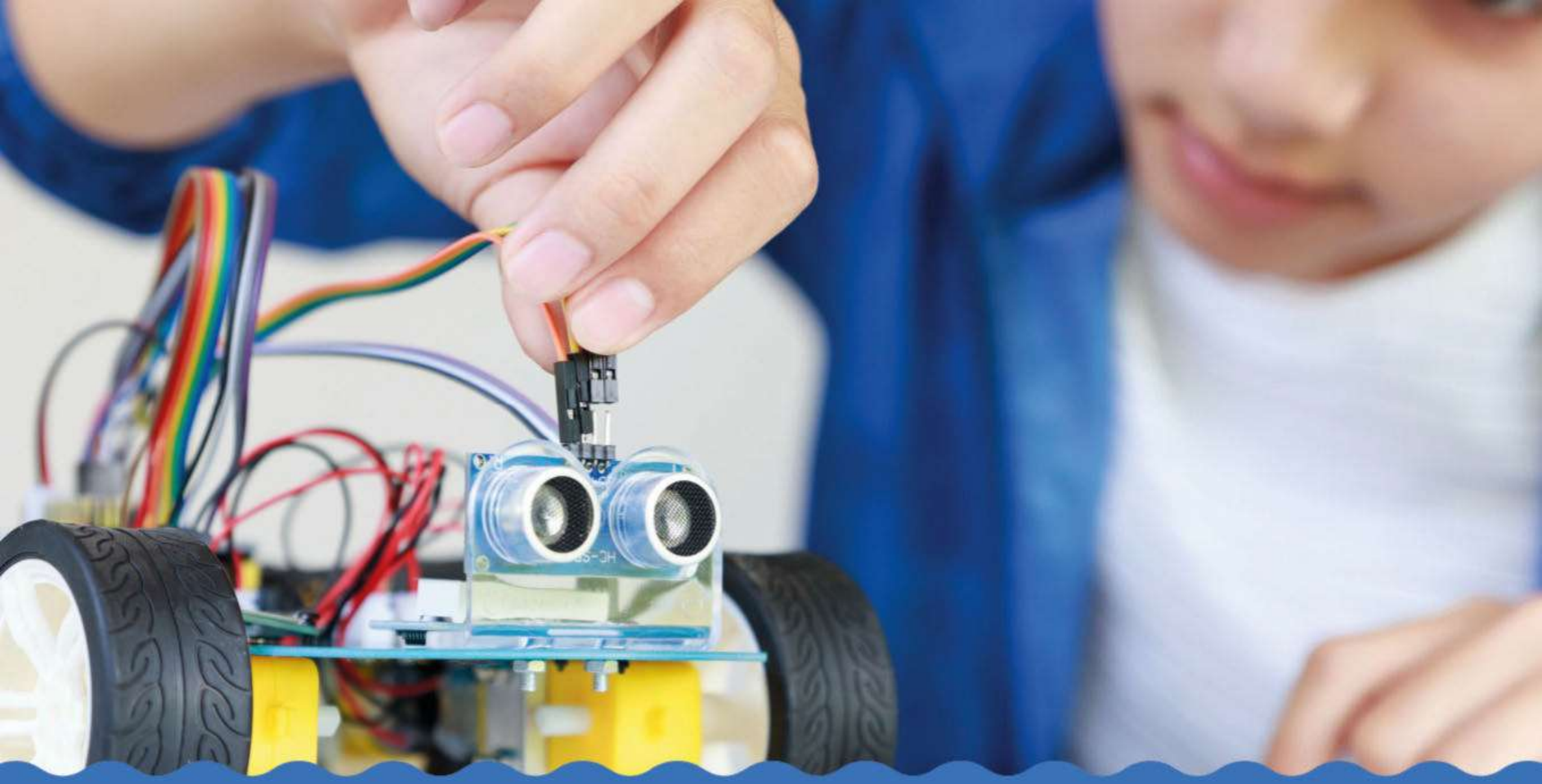


SCIENCE TECH ENVIRONMENT SPACE HISTORY TRANSPORT



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WELCOME

Issue 179

"If gravity was a little stronger, the Sun would have burned out billions of years ago"

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What if there was no gravity?
PAGE 28

Nearly 30 years ago, a giant comet hit Jupiter after being pulled in by the gas giant's gravity and was torn apart by its gravitational tidal forces. The biggest fragment of Comet Shoemaker-Levy 9 crashed into Jupiter on 18 July 1994 with the force of 6 million megatonnes of TNT, creating a dark spot in the upper atmosphere that can be seen in the image above: it was 7,500 miles wide – or about the same diameter as Earth. All of this was made possible by the force of gravity, and though space is where the most spectacular examples of gravity in action can be found, in this issue of **How It Works**, we'll explore how this fundamental force affects the tiniest things in nature right up to cosmic-scale events. What would the universe be like without gravity? Find out on page 28. Enjoy!

Ben Biggs
EDITOR

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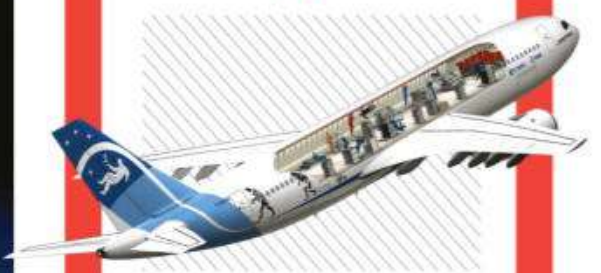

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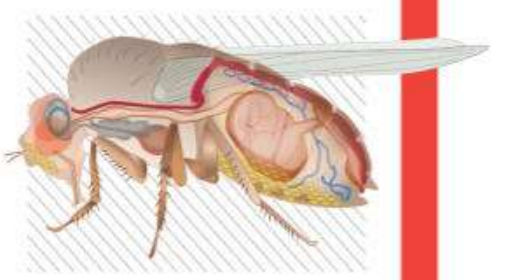

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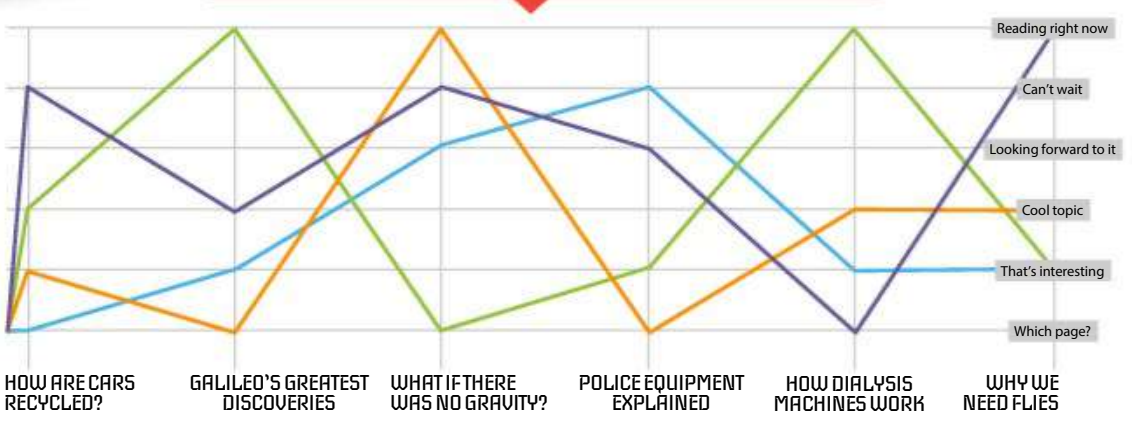

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SCOTT
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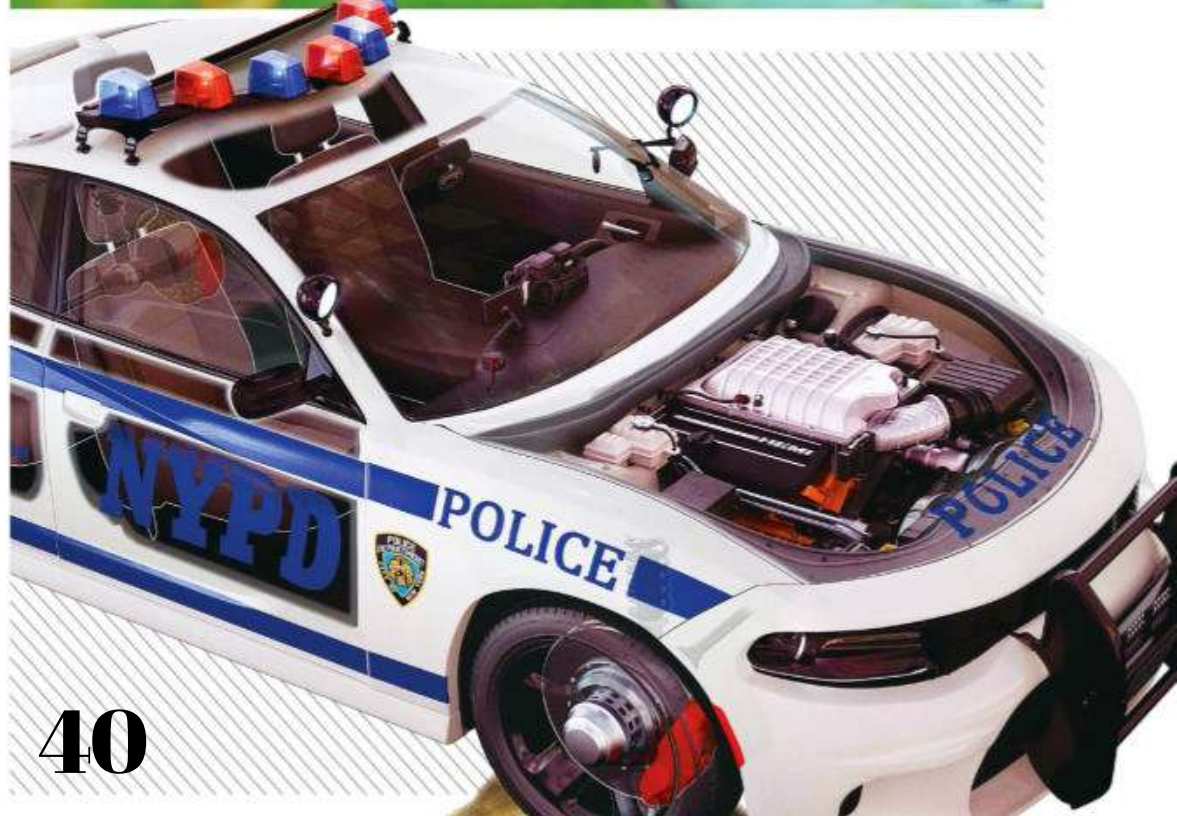

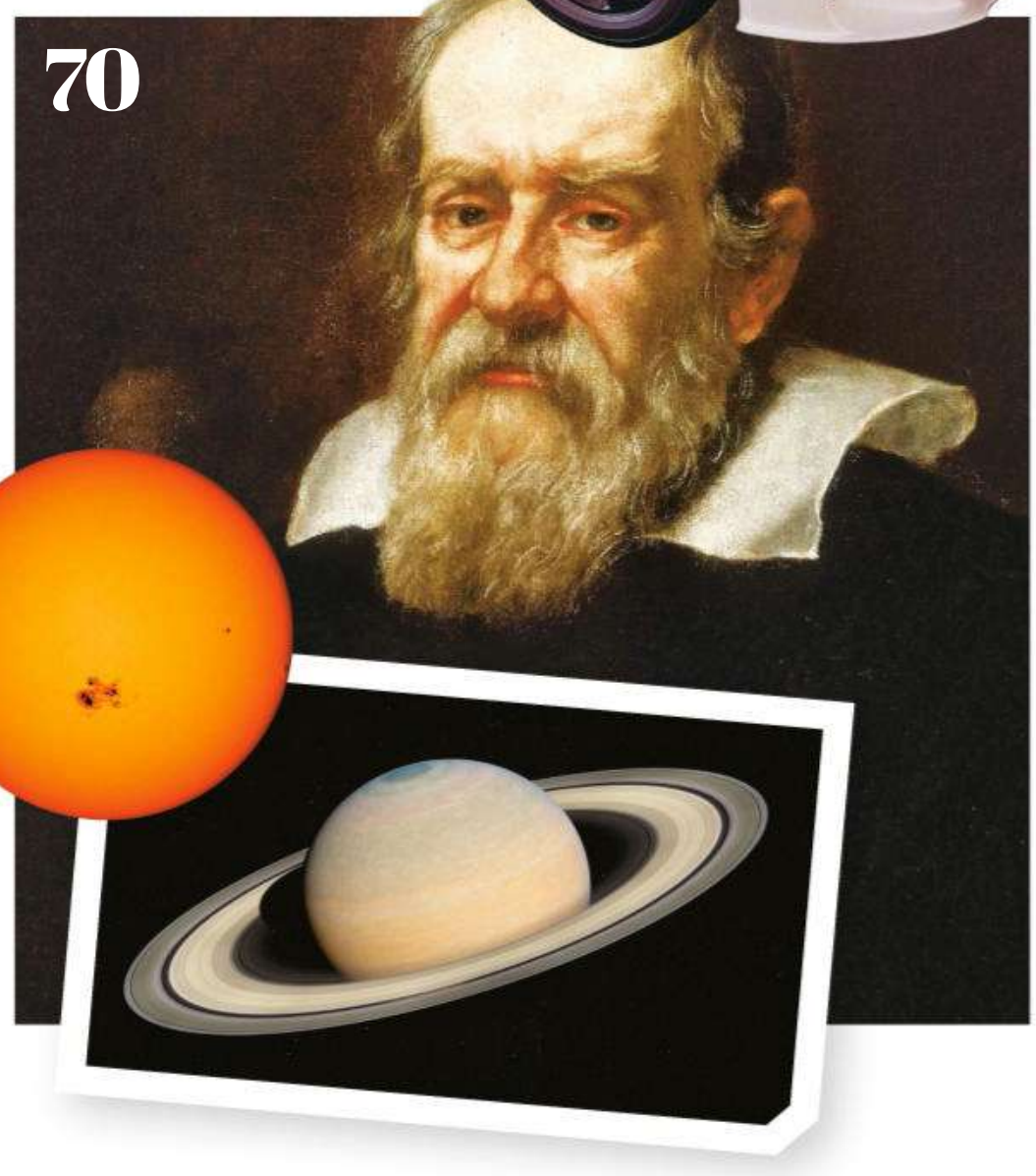

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A TELESCOPE KIT AND HOW IT WORKS SUBSCRIPTION

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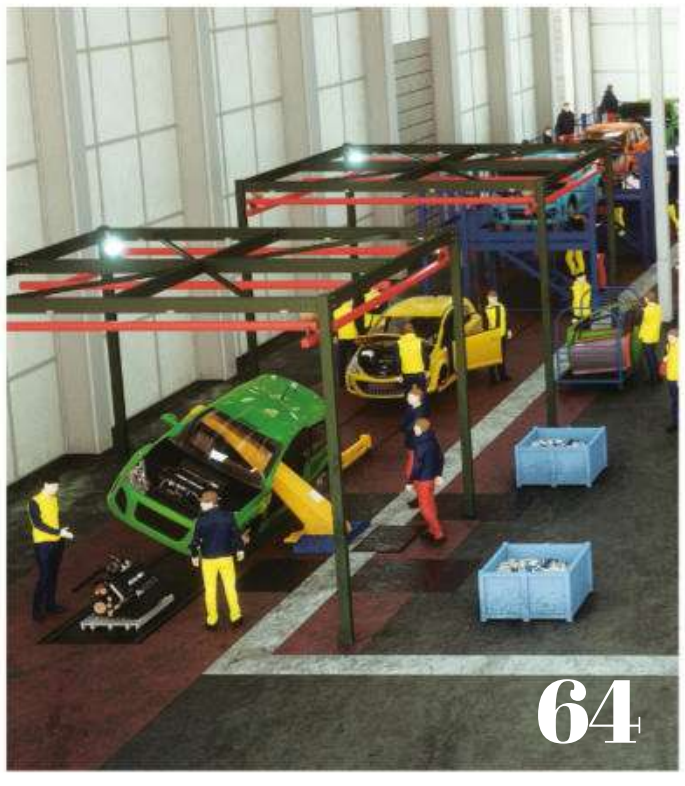

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GO TO PAGE 26 FOR GREAT DEALS

Glowing beaches

In Jervis Bay, Australia, microscopic phytoplankton turn the beach into a bioluminescent dream scene. The phenomenon, known as ‘sea sparkle’, is produced by single-celled marine plankton called *Noctiluca scintillans*. They produce the blue glow through an internal chemical reaction in which a light-emitting compound called luciferin is oxidised by an enzyme, resulting in bioluminescence.

© Getty

Canada

Walking in space

On 28 April 2023, NASA astronaut Stephen Bowen and United Arab Emirates astronaut Sultan Al Neyadi exited the International Space Station (ISS) and ventured beyond the station's Quest Joint Airlock on a seven-hour spacewalk. Seen here in their Extravehicular Mobility Unit spacesuits, Bowen was the first to leave the ISS, with Al Neyadi's legs dangling out behind him.

© NASA

When lightning strikes

The One World Trade Center (WTC) in New York acts like a 104-floor lighting rod. It's constructed from conductive materials that turn it into a huge Faraday cage, preventing any electrical current from passing into the interior. Lightning strikes a group of rods at its roof that redirect the electrical energy down the sides of the building and discharge it into the bedrock beneath.

© Getty

Nerve break

This peripheral nerve – one outside the brain or spinal cord – has been fractured. Nerve cells are coated in protective cells called Schwann cells, made up of layers of protein and fat called myelin (brown circles). Myelin also acts as electrical insulation around the conducting nerve that transmits electrical impulses. The nerve axons (purple) act like electrical cables to send information around the body.

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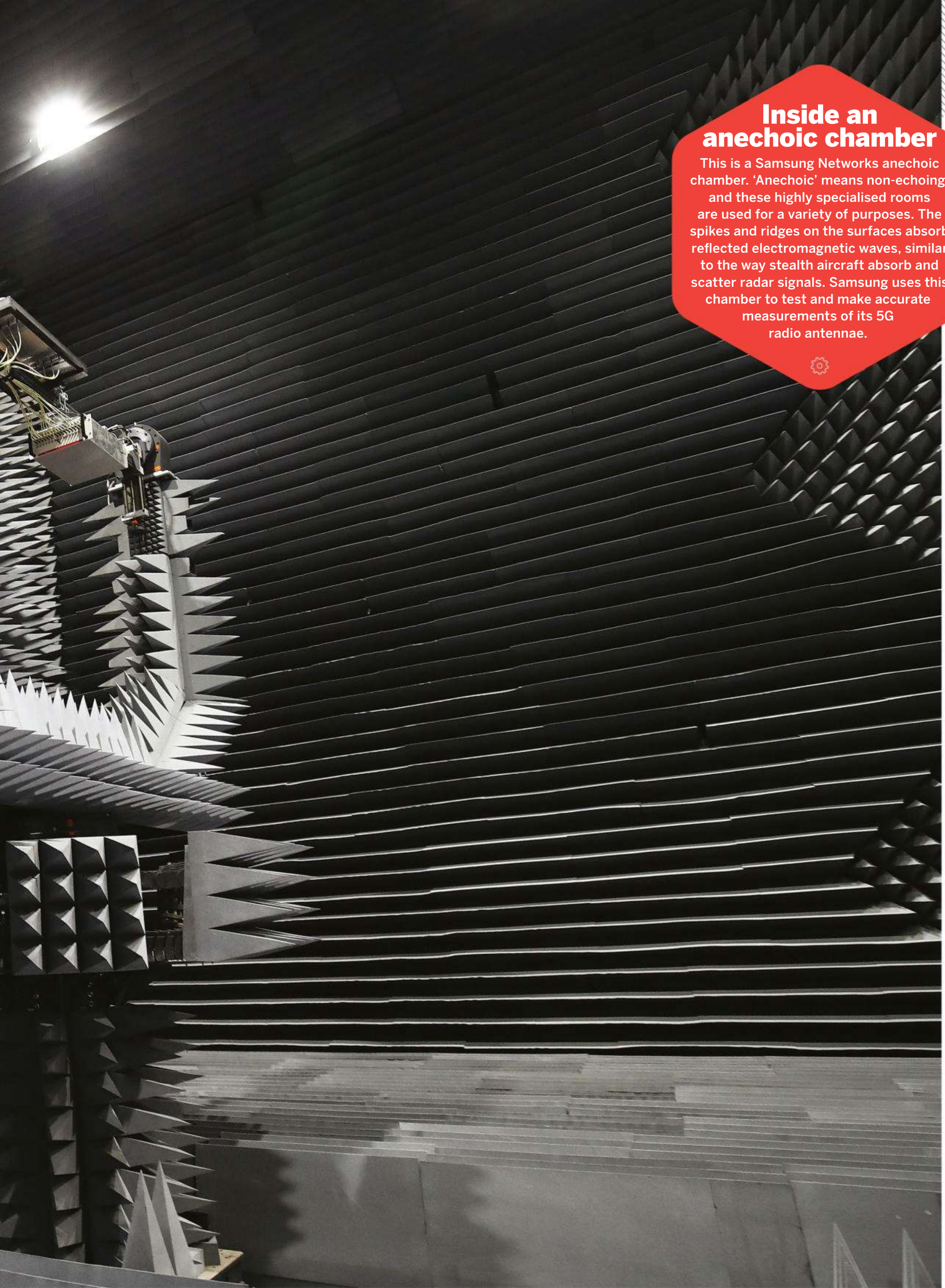


Inside an anechoic chamber

This is a Samsung Networks anechoic chamber. ‘Anechoic’ means non-echoing, and these highly specialised rooms are used for a variety of purposes. The spikes and ridges on the surfaces absorb reflected electromagnetic waves, similar to the way stealth aircraft absorb and scatter radar signals. Samsung uses this chamber to test and make accurate measurements of its 5G radio antennae.

© Getty

The progress of climate change has accelerated in recent years despite political pledges to curb greenhouse gas emissions

PLANET EARTH

Earth is getting hotter despite government pledges

WORDS **TEREZA PULTAROVA**

Average global temperatures are rising at an ever faster rate despite pledges by world leaders to tackle climate change. A new study found that the pace of global warming has accelerated in recent years despite political commitments to curb the progress of the temperature rise to 1.5 degrees Celsius compared to preindustrial times. Global temperatures increased on average by 1.07 degrees Celsius in the decade from 2010 to 2019, but the average rise in the decade from 2013 to 2022 was 1.14 degrees Celsius. That means that the pace of human-induced climate change is accelerating at a rate of over 0.2 degrees Celsius per decade. The researchers said that the still-rising levels of human-made greenhouse gas emissions are the main culprit.

In 2015, at the United Nations Climate Change Conference in Paris, leaders from 195 nations agreed to work towards limiting global warming to 1.5 degrees Celsius compared to preindustrial times. Despite this, emissions of key greenhouse gases are at an all-time high. In the last decade, humankind has been releasing about 54 gigatonnes of carbon dioxide every year into Earth's atmosphere through various industrial activities. The failure to curb these emissions means that humankind can now only release about 250 more gigatonnes of carbon dioxide before global warming reaches the 1.5 degrees Celsius limit.

In a previous carbon budget assessment in 2020, researchers found that humankind still had over 500 gigatonnes of carbon dioxide left to reach the threshold, which shows that without significant changes, the world will be through its global carbon budget in less than five years. "Even though we are not yet at 1.5 degrees Celsius warming, the carbon budget will likely be exhausted in only a few years, as we have a triple whammy of heating from very high carbon dioxide emissions, heating from increases in other greenhouse gas emissions and heating from reductions in pollution," said Professor Piers Forster, director of the Priestley Centre for Climate Futures at Leeds University. "If we don't want to see the 1.5 degrees Celsius goal disappearing in our rear-view mirror, the world must work much harder and urgently at bringing emissions down."

Did you know?

331.5 million tonnes of CO_2 was released by the UK in 2022

Researchers describe the results as a wake-up call and stress that with every small increment in average global temperatures, the world is set for more frequent and severe weather disasters such as droughts, floods and tropical storms. "It's critical that policy makers and the general public be made aware of how quickly we are changing the climate through our collective activities," said Professor Peter Thorne, director of the Irish Climate Analysis and Research Units group at Maynooth University. "Already since the assessment of the physical science basis in 2021, key numbers have changed markedly, and we remain well off track globally to avert warming above 1.5 degrees."

Artist's illustration of a hypersonic cruise missile

SPACEFLIGHT

A PENTAGON-FUNDED HYPERSONIC TEST VEHICLE COULD FLY IN 2024

WORDS **ANDREW JONES**

A new experimental hypersonic cruise vehicle could be flying as soon as next summer under an initiative from the US Defense Innovation Unit (DIU). The Dart AE high-speed test aircraft is being developed by Hypersonix Launch Systems following the award of a prototype contract. DART AE is a three-metre-long, 300-kilogram scramjet-powered technology demonstrator that can reach speeds of up to Mach 7.

The DIU, which operates under the US Department of Defense (DoD), describes itself as an organisation focused on accelerating the adoption of commercial and dual-use technology to solve operational challenges at speed and scale. The Pentagon is pursuing research and development of hypersonic defence programs. As part of this, the DIU has rolled out the high-cadence testing capabilities (HyCAT) project, which brings opportunities for commercial companies to develop reusable and low-cost test vehicles and reduce strain on DoD resources.

Lieutenant colonel Nicholas Estep, HyCAT program manager, revealed that the DIU is refining the details of the mission, including the flight conditions, the launch provider and the location for next year's first fully integrated autonomous flight of DART AE.

ANIMALS

The world's most painful ant sting targets nerves like scorpion venom

WORDS **SASCHA PARE**

Ants that inflict the world's most painful stings do so by injecting venom that targets their victim's nerve cells. Australian green-head ants (*Rhytidoponera metallica*) and bullet ants (*Paraponera clavata*), found in Central and South America, are not to be messed with. These insects' stings unleash a flood of toxins that cause trembling and uncontrollable and long-lasting pain in humans and other mammals. In his 2016 book *The Sting of the Wild*, entomologist Justin O. Schmidt described being stung by a bullet ant as "pure, intense, brilliant pain. Like walking over flaming charcoal with a three-inch [eight-centimetre] nail embedded in your heel." Victims of these ants have also likened the pain to that of being shot, giving the insect its name. "Bullet ant stings can be painful for up to 12 hours, and it's a deep drilling pain you feel in your bones, with sweating and goosebumps," said Sam Robinson, a biopharmacologist at the University of Queensland's Institute for Molecular Bioscience.

Now, Robinson and his colleagues think they know how these ants pack such vicious stings. In a new study, the scientists showed that the ant venom targets specific proteins in nerve cells that are involved in pain perception. Green-head and bullet ants produce toxins that bind to mammalian nerve cells when they sting. Researchers already knew bullet ants produce a substance targeting nerves called poneratoxin, but it remained unclear how this substance produced such intense and long-lasting pain.

To find out, the team investigated the toxin's effect on proteins embedded in the membranes of nerve cells called voltage-gated sodium channels, which serve a critical role in pain signalling. These channels regulate how much sodium enters and exits cells, which determines the length and strength of pain signals, supporting neurological and muscle function in animals. Many venomous animals have evolved toxins that target sodium channels, including some scorpions, such as the yellow fat-tailed scorpion (*Androctonus australis*).

The researchers found that the venoms of green-head and bullet ants, as well as another species called *Tetramorium africanum*, also target sodium channels. The ants' toxins unlock these channels and prevent them from shutting again, prolonging and intensifying the pain signal. "We discovered that the ant toxins bind to the sodium channels and cause them to open more easily and stay open and active, which translates to a long-lasting pain signal," said Robinson.

The bullet ant (*Paraponera clavata*) inflicts the world's most painful ant sting

© Getty / Alamy / U.S. Air Force

GLOBAL EYE

An artist's interpretation of what the newfound species *Iani smithi* may have looked like

HISTORY

An unearthed dinosaur could be a 'missing link'

WORDS **HARRY BAKER**

Palaeontologists have unearthed a never-before-seen raptor-like dinosaur that lived during a period of extreme climate change around 100 million years ago. Researchers think the newfound species could be an evolutionary 'missing link' between two key dinosaur groups. The newly described species, *Iani smithi*, belongs to the clade Ornithopoda – an extinct group of non-avian, mostly bipedal dinosaurs with several birdlike features. It's unclear how large this species was, but it likely grew to around three metres long. One of the standout features of *I. smithi* is its powerful jaw, which hints that the species exclusively ate plants.

Researchers unearthed a partial skeleton of a suspected *I. smithi* juvenile in Utah's Cedar Mountain Formation in 2014. The bones, which include a nearly complete skull, several vertebrae and limb bone fragments, date to around 99 million years ago, during the mid-Cretaceous period. "Finding *Iani* was a stroke of luck," said Lindsay Zanno, a palaeontologist at North Carolina State University. "We knew something like it lived in this ecosystem because isolated teeth had been collected, but we weren't expecting to stumble upon such a beautiful skeleton."

The newly described genus *Iani*, of which *I. smithi* is the sole species, was named after Janus, the Roman god of change, who is often depicted with two faces. Researchers chose this name because *I. smithi* existed during a period of extreme climate change that altered the trajectory of dinosaur evolution. During the mid-Cretaceous period, Earth faced extreme climate change driven by naturally increasing carbon dioxide levels that caused global temperatures to soar and sea levels to rise. As a result, many large herbivores, such as the early ornithopods and gigantic, long-necked sauropods, and their predators died out. In their place, multiple lineages of smaller plant-eating dinosaurs emerged, as did a new generation of predators, including theropods such as *Tyrannosaurus rex*.

The team suspects that *I. smithi* may have been a 'last gasp' ornithopod species that managed to adapt quickly enough to the changing ecosystems to survive where a majority of its relatives did not. "This dinosaur stood on the precipice, able to look back at the way North American ecosystems were in the past, but close enough to see the future coming like a bullet train," Zanno said. The team thinks *I. smithi* could be the missing link between early ornithopods and the genus *Parasaurolophus*. This group of duck-billed ornithopods with large head crests was one of the most successful herbivorous groups in the period following the climatic shift in the mid-Cretaceous.

PLANET EARTH

SCIENTISTS HAVE DISCOVERED HOW PHOTOSYNTHESIS STARTS

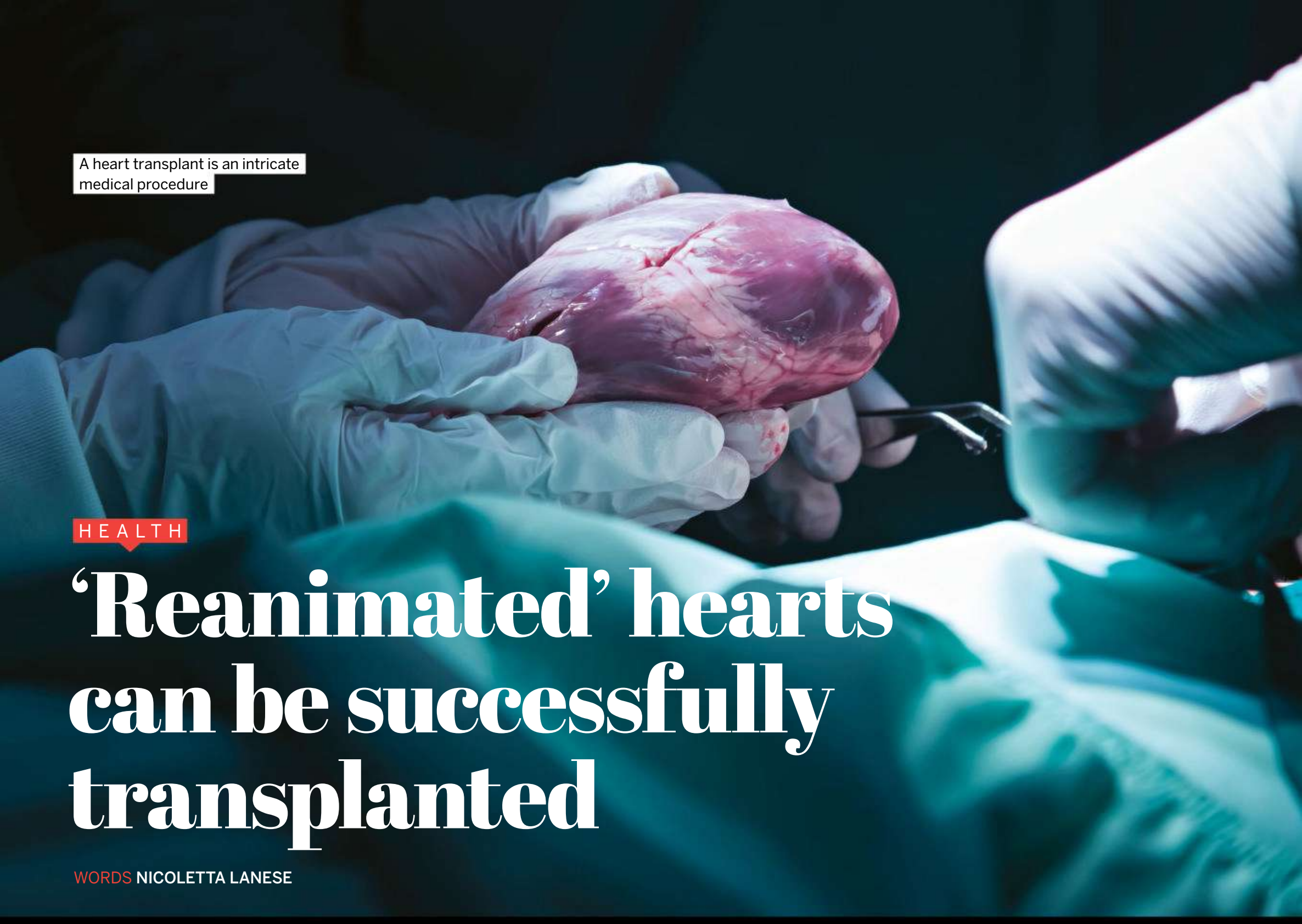
WORDS **JOANNA THOMPSON**

Light is the basis for almost all life on Earth. Using energy from the Sun, plants, algae and some bacteria create complex sugar molecules that serve as the foundations for most of nature's food chains. But parts of this chemical reaction have remained somewhat of a mystery... until now. For the first time, researchers have observed the start of photosynthesis, starting with a single photon. When light hits a plant's chloroplast, it absorbs energy from the incoming photons and uses it to turn carbon dioxide and water into glucose and oxygen, thanks to a green pigment called chlorophyll.

In a new study, researchers looked at purple photosynthetic bacteria, which share an ancient ancestor with modern-day plants and algae. They set up a photon source that spits out just two photons at a time. During each test, the first photon fired out was absorbed by an ultra-sensitive detector, while the other struck the bacteria's equivalent of a chloroplast. Sure enough, when the second photon hit its target, photosynthesis started.

The researchers performed this test over 1.5 million times to ensure that the second photon, rather than some outside force, was triggering the chemical reaction. This confirmed that just one photon was enough to set off photosynthesis.

An illustration of a single photon drifting towards a plant to kick-start photosynthesis



A heart transplant is an intricate medical procedure

HEALTH

‘Reanimated’ hearts can be successfully transplanted

WORDS NICOLETTA LANESE

A method for ‘reanimating’ organ donors’ hearts works just as well as the standard approach to collecting hearts for transplantation, new trial data shows. If widely applied, the method could increase the heart donor pool by an estimated 30 per cent. “If we could snap our fingers and just get people to use this, I think it probably would go up even more than that,” said Dr Jacob Schroder, a transplant surgeon at the Duke University School of Medicine. “This really should be the standard of care.”

Most transplanted hearts come from brain-dead donors who’ve died due to a complete loss of brain activity, rather than circulatory death, in which the heart stops. A brain-dead patient can be declared dead before their heart stops beating, and this allows doctors to remove the heart while it’s still perfused with oxygen-rich blood, and therefore not yet damaged by a lack of oxygen. The heart is then flushed with a preservation solution, placed in an ice-filled cooler and rushed to its recipient.

In the recent trial results, doctors compared the survival rates of transplant recipients who got hearts from brain-dead donors with the survival rates of those who got hearts from donors who’d died of circulatory death. A total of 166 US-based heart transplant patients were included in the primary analysis, 86 in the brain-death group and 80 in the circulatory-death group. Six months post-surgery, the brain-death group had a 90 per cent survival rate and the circulatory-death group had a 94 per cent survival rate, suggesting that donation after circulatory death, or DCD, is an equally viable approach to heart transplants.

DCD is made possible by extracorporeal machine perfusion, which involves hooking up the donor organ to a machine that pumps blood and nutrients through its tissues. The new trial tested a perfusion system called Organ Care System Heart, made by TransMedics, the trial’s funder. The system warms the blood that it pumps through the donor hearts, as compared with other perfusion systems, which still require the organ be cooled as part of the preservation process.

Although the two groups had similar survival rates at six months, compared with the traditional heart transplant group, the DCD group had slightly higher rates of moderate to severe primary graft dysfunction, in which one or both of the heart’s ventricles show dangerous dysfunction within 24 hours of the transplantation surgery. However, none of the DCD patients had primary graft failure that resulted in retransplantation, while two people in the traditional transplant group did. Overall, the rate of serious adverse events was very low and similar in both groups, as assessed out to 30 days post-surgery. The new trial involved multiple medical centres and builds upon previous evidence in favour of DCD, which mostly drew from isolated cases and small trials performed at single centres in Australia and the United Kingdom.

Did you know?

Up to 200 heart transplants are completed each year in the UK

© Getty / Jorge Gonzalez/North Carolina State University / Jenny Nuss/Berkeley Lab

ANIMALS

‘VIRGIN BIRTH’ RECORDED IN A CROCODILE FOR THE FIRST TIME

WORDS HANNAH OSBORNE

Scientists have announced the first ever recorded case of a crocodile ‘virgin birth’ after a female that had been isolated for 16 years was discovered with a clutch of eggs. The discovery provides insights into the evolutionary origins of the trait. The American crocodile (*Crocodylus acutus*) was taken into captivity in 2002 when she was two years old and placed in an enclosure at Parque Reptilandia in Costa Rica. But in January 2018, a clutch of 14 eggs was found in the enclosure.

Virgin birth, also known as facultative parthenogenesis, is a type of asexual reproduction. Scientists have documented it in birds, sharks, lizards and snakes in captivity, among other species. Until now it had never been recorded among Crocodilia, the order that includes crocodiles, alligators, caimans and gharials.

7 of the 14 eggs produced by the crocodile were viable. Zoo caretakers incubated these eggs, but they didn’t hatch. After three months, they opened them. The contents of six was “not discernable,” but one contained a fully formed, but non-viable foetus. Genetic analysis showed it was almost identical to the mother. Researchers wrote that it was disappointing the egg failed to hatch, but that it’s not unusual for offspring born this way to suffer abnormalities and fail to thrive. Facultative parthenogenesis, they added, may be more common in species on the brink of extinction.

A ‘virgin birth’ was recorded in a crocodile at a reptile park in Costa Rica

© Getty

Tagrisso, also known as osimertinib, reduced the five-year risk of death in lung cancer patients by 51 per cent

HEALTH

A lung cancer pill drastically cuts the risk of death after surgery

WORDS JENNIFER NALEWICKI

A once-daily pill halved people’s risk of dying from a common lung cancer when they took the drug after tumour-removal surgery, new trial data shows. Made by the biopharmaceutical company AstraZeneca, Tagrisso, also known as osimertinib, reduced the five-year risk of death in lung cancer patients by 51 per cent. The study was the result of a 682-patient trial that included participants diagnosed with non-small cell lung cancer (NSCLC), one of two main types of primary lung cancer. All patients also had a mutation in the epidermal growth factor receptor (EGFR) gene, which codes for a protein found on the surfaces of cells. EGFR mutations can boost cancer’s ability to grow and spread, raising patients’ risk of cancer recurrence post-treatment.

Osimertinib essentially works by blocking the effects of common EGFR mutations. Such mutations are present in about 25 per cent of lung cancer patients worldwide. “30 years ago there was nothing we could do for these patients,” said Dr Roy Herbst, deputy director of the Yale Cancer Center in New Haven, Connecticut. “Now we have this potent drug. 50 per cent is a big deal in any disease, but certainly in a disease like lung cancer, which has typically been very resistant to therapies.”

Approximately 80 to 85 per cent of all lung cancers are NSCLC. Each year more than 127,000 Americans die from lung cancer. Patients in the trial received either a placebo or osimertinib. Five years after having their tumours surgically removed, 88 per cent of patients who took osimertinib were still alive, compared with 78 per cent of the placebo patients. “A five-year overall survival rate of 88 per cent is incredibly positive news,” Angela Terry, chair of the nonprofit EGFR Positive UK, said. “Having access to a drug whose efficacy is proven and whose side effects are tolerable means patients can be confident of and able to enjoy a good quality of life for longer.”

Unfortunately, not all lung cancer patients are tested for the EGFR gene, Herbst said. “This further reinforces the need to identify these patients with available biomarkers at the time of diagnosis and before treatment begins.” Tagrisso was first approved by the US Food and Drug Administration in 2017, when the pill was cleared as a treatment for patients with advanced NSCLC whose tumours carried certain EGFR mutations.

Original notes and designs from The National Archives collection are included in the exhibition

ADVERTORIAL

SCIENCE

Clothes that grow with children are on display at the Spirit of Invention exhibition

An aeronautical engineer has invented expandable clothes for children that address fast fashion and the short-term use of children's clothes. Ryan Mario Yasin used his experience in satellite material technology to develop a fabric that stretches as young children grow, and will therefore fit them for many years. Having combined his science expertise with the everyday difficulties he experienced when buying clothes for his growing nephew, the practical patent was granted.

Ryan is the founder of Petit Pli, a company selling space-inspired expandable children's clothes, and his invention is on display at a new interactive exhibition at The National Archives in London. The free exhibition is called Spirit of Invention, and its innovative artefacts instil just that. Showcased at the event are a range of novelty and revolutionary creations, from pioneering Victorian masterpieces to the latest technological inventions – each with a unique story to tell.

Each artefact comes from a source deep in historical archives, and one of the earliest designs on display at the exhibition is for an 1852 typewriter that enabled blind people to utilise this breakthrough device of the time. Other early archived inventions on display include the Bonafide Ventilating Hat – a Victorian top hat with an inbuilt fan for the wearer's comfort – and the first combined knife and fork by surgical instrument company Messrs Arnold & Sons.

The exhibition, which was co-curated by British entrepreneur Ruth Amos and local children from Darell Primary School, reminds visitors of how technological capabilities dictate the transformative power of inventions. Some of the inventions that rely on modern technology include a water filtering system that recycles shower water for use in washing machines, an LED necklace to indicate pollution levels in the surrounding air and compostable lampshades produced by fungi.

The National Archives is home to millions of fascinating documents from the annals of British history, including designs registered with the Board of Trade from 1839 onwards. Serving as a window into over 150 years of trailblazing creativity, The National Archives has opened its doors to share a selection of this inspiring work. As well as getting insight into the inventions and the challenges that led to these solutions, those who visit the exhibition are invited to explore their own creative abilities. Visitors are supplied with crafting materials and given designated areas to engineer their own inventions in, with the first Sunday of every month featuring activities based around a new theme. To celebrate the exhibition, The National Archives has launched a design competition that encourages visitors and members of the public to submit their own inventions. This is now open, and entries with the most potential will be displayed in the gallery alongside the work of some of Britain's historic inventors.

DETAILS

WHERE TO VISIT:
The National Archives, Richmond, London

WHEN TO VISIT:
Open now until 29 October 2023, Tuesday to Sunday

GET IN TOUCH:
Website: **nationalarchives.gov.uk/spirit-of-invention/**
Twitter: **@uknatarchives**
Facebook: **TheNationalArchives**
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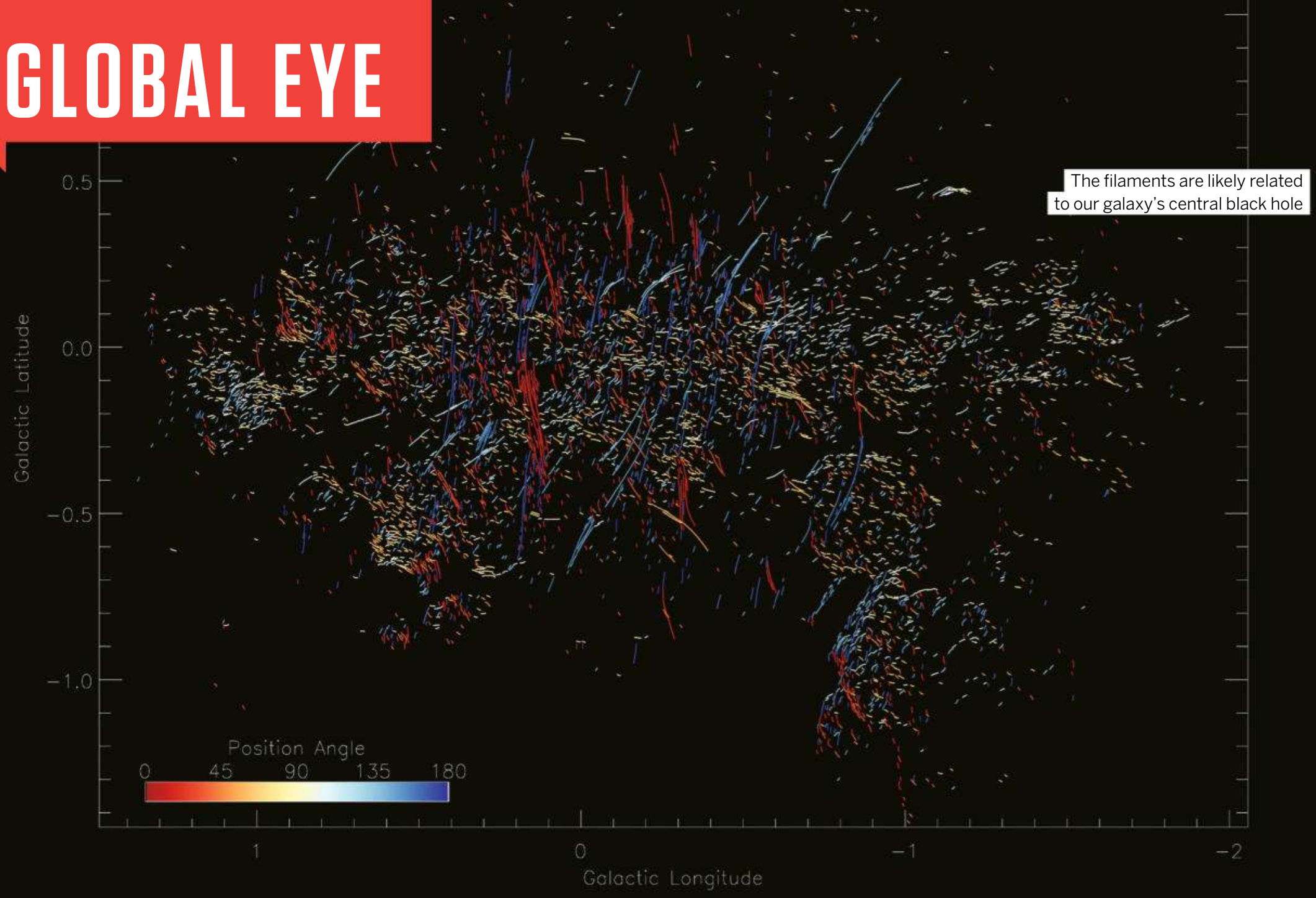
Part of the Spirit of Invention's charm is in incorporating historical inventions and their creators' musings that reflect the technological era with futuristic items. Colin Furze's hoverbike explores future transport possibilities in this way. This flying bicycle combines two drones, at the front and rear of the vehicle, with a central frame similar in shape to a standard bicycle. It has two engines to propel the vehicle while balancing the weight and enabling the rider to hover over the ground in forwards, backwards and sideways motions. This hoverbike was built at the inventor and former plumber's home, highlighting the risks that many inventors navigate in order to be the first to achieve a new product.

www.nationalarchives.gov.uk/spirit-of-invention/

© Jayne Lloyd, The National Archives



The filaments are likely related to our galaxy's central black hole

ASTRONOMY

Hundreds of ancient, invisible structures discovered near our galaxy's centre

WORDS **BRANDON SPECKTOR**

Astronomers have discovered hundreds of strange, string-like structures at the centre of our galaxy, possibly tracing the violent path of an ancient black hole eruption. According to new research, each of these previously unknown filaments measures between five and ten light years in length, thousands of times the distance between the Sun and Pluto, but is visible only in radio wavelengths, meaning the structures were likely created by bursts of high-energy particles that are invisible to the naked eye.

When seen together, the hundreds of crackling filaments seem to point directly at our galaxy's central supermassive black hole, suggesting that they may be the unhealed scars of an ancient, high-energy black hole outburst that tore through the surrounding clouds of gas. "It was a surprise to suddenly find a new population of structures that seem to be pointing in the direction of the black hole," said Farhad Yusef-Zadeh, a professor of physics and astronomy at Northwestern University in Illinois. "I was actually stunned when I saw these... and we found that these filaments are not random, but appear to be tied to the outflow of our black hole."

The Milky Way's central supermassive black hole, dubbed Sagittarius A*, or Sgr A*, is a cosmic monster with more mass than 4 million Suns. Its intense gravitational pull binds our galaxy together, but its monstrous appetite has also resulted in some severe cases of interstellar indigestion. Prior radio observations of Sgr A* conducted by Yusef-Zadeh's team turned up enormous bubbles of energy towering 25,000 light years above each side of the black hole's maw, as well as roughly 1,000 vertical strand-like radio filaments emanating from Sgr A* like the strings of an immense harp. Both of these mysterious phenomena were likely created by an ancient outburst from our galaxy's black hole.

To detect the new crop of spindly horizontal radio filaments, the researchers enhanced recent observations from the South African Radio Astronomy Observatory's MeerKAT telescope, an array of 64 interlinked radio antennae in South Africa, and reduced the background noise of nearby energy sources. The resulting images showed that the newfound filaments are about as thin as the previously discovered forest of vertical filaments. However, these new strands of energy appear to radiate from only one side of Sgr A*, whereas the previously discovered filaments line up all across the galactic centre. The newly discovered structures are also much shorter than their vertical counterparts, and there are far fewer of them. Despite these cosmetic differences, the researchers suspect the newfound structures were created by a similar eruption of energy from our galaxy's central black hole that may have occurred around 6 million years ago. "It seems to be the result of an interaction of that outflowing material with objects near it," Yusef-Zadeh concluded. However, he added, his team must make new radio observations to "continually challenge our ideas and tighten up our analysis" of the violent past life of the monster at the centre of our galaxy.

Scientists found fungi are able to regulate their own body temperature

PLANET EARTH

Fungi seem to ‘sweat’ to stay cool

WORDS **ETHAN FREEDMAN**

Mushrooms, and possibly all fungi, have the ability to cool down by ‘sweating’ away water. Researchers at Johns Hopkins University used an infrared camera to snap pictures of mushrooms in the woods. Infrared cameras can visualise the relative temperatures of each object in a photo, and the team noticed something odd: the mushrooms seemed to be colder than their surroundings. Scientists had previously observed that mushrooms tend to be colder than their environments. However, microbiologist Dr Arturo Casadevall said he had never heard of the phenomenon, so the team decided to find out if this cooling effect applied to all fungi. In addition to photographing wild mushrooms, the researchers grew and photographed different types of fungi in the laboratory and found the same effect – the fungi were colder than their surroundings. This was even the case with their culture of *Cryomyces antarcticus*, a fungus that grows in Antarctica.

The fungi seem to cool down through evapotranspiration of water from their surface, meaning, essentially, they sweat. Think about coming out of the shower. When you’re covered in water, you feel cold because some of the water on your skin is evaporating, taking heat with it. The team then created a sort of mushroom-powered air conditioner. They put mushrooms, *Agaricus bisporus*, commonly sold in supermarkets as portobello and white mushrooms, among other names, into a Styrofoam box with a hole on each side. A fan was placed outside one of the holes, and they put this ‘MycoCooler’ into a larger container and turned the fan on to circulate air over the mushrooms. After 40 minutes, the air in the larger container had dropped from about 37.8 degrees Celsius down to about 27.8 degrees Celsius. The mushrooms had lowered the temperature through evaporative cooling, using up heat in the air to convert liquid water into gas. The scientists are still unsure why fungi might want to keep cool.

Did you know?

There are around 150,000 described fungi species

Researchers speculate that it might have something to do with creating optimal conditions for spore formation, or it may help fungi spread their spores. By altering the temperature, they might be causing tiny winds that can blow the spores around. It’s also possible that this phenomenon is due to something else entirely. For example, evapotranspiration also increases humidity, and when asked if it’s possible that the fungi are trying to keep humid and the cooling is simply a by-product, Casadevall said it was conceivable. Understanding the reason behind this cooling phenomenon in mushrooms and other fungi could help us understand how fungi interact with their environment and other organisms, ourselves included.

SPACEFLIGHT

THE PENTAGON CONFIRMS IT’S BUYING STARLINK SERVICES FOR UKRAINE

WORDS **ANDREW JONES**

Elon Musk’s SpaceX has been supplying Ukraine with Starlink terminals since the Russian invasion of the country in 2022, providing vital communications after the destruction of infrastructure within the country. However, SpaceX stated in September 2022 that it couldn’t continue funding the Starlink service for Ukraine, and had asked the Pentagon to step in and cover costs. A deal is now in place to continue providing the vital communications services.

“Satellite communications constitute a vital layer in Ukraine’s overall communications network, and the department contracts with Starlink for services of this type,” cited a DoD statement. “We continue to work with a range of global partners to ensure Ukraine has the satellite and communication capabilities they need.” The Pentagon did not reveal details of the contracts, citing operational security concerns.

SpaceX expressed concerns earlier this year over the use of Starlink by the Ukraine military for offensive means. Company president and chief operating officer Gwynne Shotwell stated that the service was “never meant to be weaponised”.

A SpaceX Falcon 9 rocket launching a Starlink mission from Cape Canaveral in Florida in 2022

© Getty / Farhad Yusef-Zadeh/Northwestern University

WISH LIST

The latest tech for SUMMER

GENEINNO S2 DIVING SCOOTER

WWW.GENEINNO.US $539 (APPROX. £423.50)

It's a superfast sea scooter that can reach up to 1.2 metres per second. Generating ten kilograms of thrust, the Geneinno S2 is a snapping scooter that will have you zipping below the water's surface in no time. With its 30-metre-waterproof performance, you'll be able to see new parts of the sea you've never seen before. It also comes with a battery life of up to 45 minutes for maximum exploration time. This gadget is great for snorkelling, free diving and scuba diving, but if your children want to have a go in the pool, there are parental controls for the scooter using the accompanying app.

RAY-BAN STORIES

WWW.RAY-BAN.COM FROM £299 / $299

Document your day in the sunshine with the sleek and stylish Stories sunglasses, created in collaboration between Ray-Ban and Meta. Using the integrated five-megapixel cameras, you can take photos and videos with ease and at consistently high quality thanks to built-in automatic light adjustment. There are also discrete open-ear speakers and three built-in microphones so you can take calls and get great sound quality for your videos. There are two options to control the glasses: by voice or by touch. A simple "Hey Facebook" and your glasses will either snap a shot, take a call, pause music or begin recording. The same can be achieved with a single touch of the hyper-responsive touchpad. Then you can download all of your content to the Facebook View app to review.

JISULIFE LIFE3 NECK FAN

WWW.JISULIFE.COM £36.62 / $45.99

Using its dual-sided turbine motor, the Jisulife Life3 Neck Fan will help you beat the heat this summer. It draws in air and produces a natural breeze from 78 different outlets around your neck and head. It's easy to forget you're wearing the Life3 as it only weighs 254 grams and produces around 25 decibels of sound – similar to someone breathing a short distance away – during use. There are three air speeds to choose from for up to 16 hours of cooling time. It also only takes around 3.5 hours to complete a full recharge, ready for another day of cooling you down.

SPYRATHREE

WWW.SPYRA.COM

£134 / $179

The SpyraThree isn't your typical water pistol – it's a fully automatic, battery-powered water blaster that pressurises the water in its tank to deliver an epic power shot every time. There are three game modes to enjoy with the SpyraThree: a freestyle open mode, rapid burst mode and league mode for ultimate gameplay. A full tank can deliver more than 22 water blasts in open mode, which can reach an impressive 10.5 metres. In league mode, there's also the option to charge up a power shot to release a burst of water up to 15 metres. The gun comes with a tactical display that monitors your battery status and tank reserves so you know when it's time to reload. Refilling and repressurising your water ammo takes just ten seconds to get you back in the game in no time.

LINK FLIPSHOE

WWW.LINK-SHOES.COM $119 (APPROX. £93.50)

Move aside flip-flops, there's a new summer shoe in town: the LINK Flipshoe. The shoes offer all the flexibility and convenience of a traditional flip-flop without the strap and unprotected arch, and aren't slippery in wet conditions. Created by manufacturers Link, Plug & Walk, these shoes have been designed to be worn in all different weather conditions and scenarios. No longer will you have to endure the irritation of sand rubbing between your toes and the strap after a day at the beach. The Flipshoe lets your feet breathe in the summer sunshine without compromising on comfort and protection. They are also quick-drying and come in an array of vibrant colours.

MYCANOE SOLO 2

WWW.ORICANOE.COM £622.99 / $799

As far as foldable canoes go, you might be hard-pressed to find one as compact as the MyCanoe Solo 2. Perfect for a paddle on a lake this summer, this convenient canoe weighs only 8.6 kilograms, but can support up to 136 kilograms of passenger weight. In just two minutes, the Solo 2 goes from a compact carry case to a full-sized canoe. Thanks to its ultraviolet-treated, durable polypropylene material, it's puncture and erosion resistant, which is great for trips through rocky shores and shallow seawater.

© Getty / MyCanoe / Jisulife / Ray-Bans / Geneinno / Link, Plug & Walk / Spyra

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SPECIAL

WHAT IF THERE WAS NO GRAVITY?

How this fundamental force controls the way things move on Earth and throughout the universe

WORDS **ANDREW MAY**

DID YOU KNOW? The force of gravity between two protons is a thousand decillion times weaker than the electromagnetic force

Gravity is something we all take for granted. It's the force that holds us to the surface of the Earth and what makes things fall. But it's much more than that, too. It's what holds Earth together and gives the planet its roughly spherical form. It's what keeps Earth moving in its orbit around the Sun, ensuring that we always have the heat and light we need to live. In fact, gravity is one of the most fundamental things in the universe – the force that holds everything from asteroids to galaxies together.

Gravity is one of four fundamental forces, alongside electromagnetism and the two types of nuclear force. On very small scales it's by far the weakest of these forces, but it comes into its own at large distances. That's because the nuclear forces have a very limited range, while electromagnetic forces tend to get cancelled out because electric charge can be either positive or negative. Gravity, on the other hand, always acts in the same direction – it's a force of attraction, which means there's no limit to its range. And it's a very democratic force, operating with equal effect between any two objects having mass. For these reasons, it's far and away the most important force governing the universe on large scales.

Gravity also played a key role in the formation of the universe by causing matter to clump together and form atoms, stars and galaxies. If gravity never existed, then the universe would have remained completely featureless and the same everywhere. You might worry what would happen if gravity was suddenly 'switched off', but this is something that our best theory of gravity – the one put together by Albert Einstein – says is impossible. There are, however, alternative theories that allow for a variable strength of gravity. Under these theories, if the force of gravity was suddenly reduced to zero, then the principle of inertia would take over. This explains that when the force acting on an object is suddenly switched off, it will continue to move in a straight line at whatever speed it was going at. In the case of gravity, this means that people would start to drift off the surface of the planet, satellites would fly tangentially out of their orbits and stars and galaxies would gradually disintegrate.

Did you know?

Neutron stars are around the size of a city, but have immense mass

Scientists sometimes speculate what might have happened if the universe was created

Gravity holds galaxies together and can sometimes cause two galaxies to interact

© Getty / NASA

SPECIAL

Gravity is the main force governing the orbits of satellites like the Hubble Space Telescope

with a slightly stronger or weaker force of gravity. It turns out that if gravity was a little weaker, the Sun's core would never have become hot and dense enough to trigger the nuclear reactions that produce sunlight, whereas if it were a little stronger the Sun would have burned out billions of years ago. Needless to say, either of those situations would have been disastrous for any possibility of life on Earth.

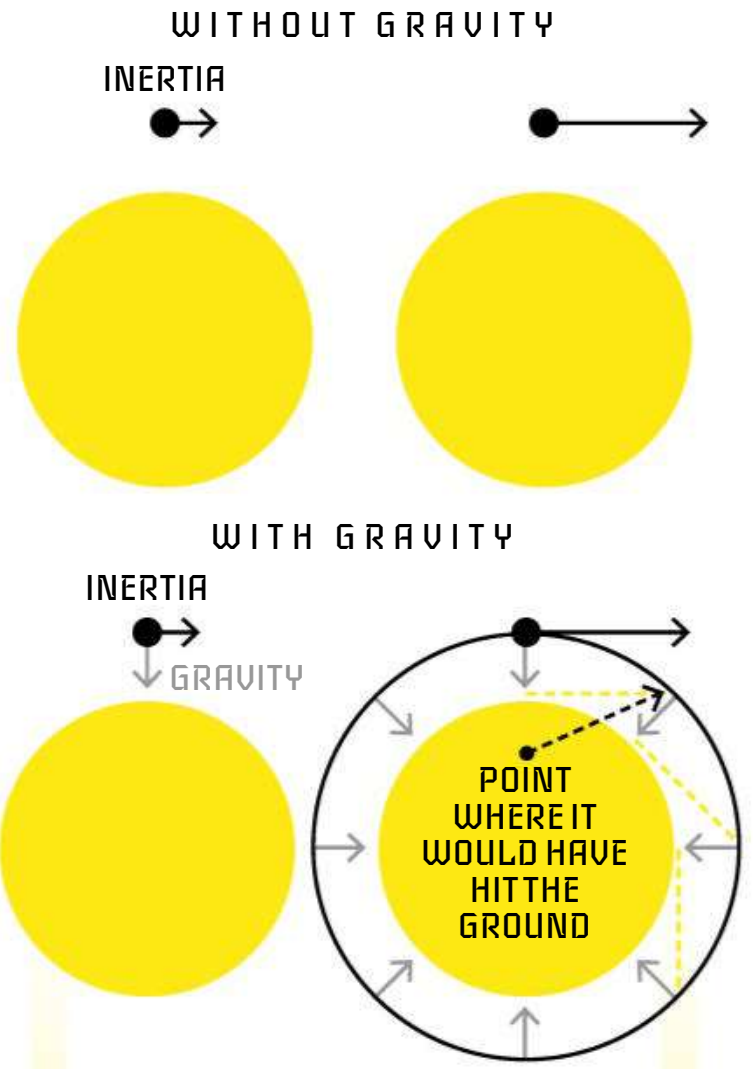
Although all objects exert a gravitational pull on all other objects, the only thing that's close enough and massive enough for us to be aware of it is the Earth itself. The main effect of Earth's gravity is to give weight to objects. This isn't the same as the object's mass, which is simply a measure of the amount of matter it contains, typically expressed in kilograms. An object's mass remains the same wherever it is in the universe, and determines how strongly it resists any force that's applied to it. In contrast, an object's weight is the amount of force that a gravitational field exerts on it. Strictly speaking, weight should be measured in units of force, such as newtons, but because it's always proportional to mass when we're on Earth's surface, we usually measure it in kilograms instead. But on a smaller planet an object's weight would be lower, even though its mass remains the same. For example, a person weighing 50 kilograms on Earth would only weigh around 18 kilograms on Mars.

Although the strength of Earth's gravity decreases with increasing distance, it still has a perceptible effect way out in space. It's what keeps satellites and the Moon in orbit around the planet. In fact, the Moon is large enough for its gravity to have a reciprocal effect on the Earth, which we see in the form of ocean tides. These are caused by the difference in the strength of the Moon's gravitational pull on the water on opposite sides of the planet, causing the seas to bulge outwards slightly.

Did you know?

The first artificial satellite, Sputnik, was launched in 1957

In the wider universe, gravity can produce some spectacular effects. It's the force that holds galaxies together, and the primary cause of the intricate spiral patterns that many of them display. It's also responsible for binding multiple galaxies together into large groups and clusters. And gravity is crucial to the formation and behaviour of black holes, too. When a large star runs out of nuclear fuel, it's because it's unable to withstand the pull of its own gravity, so it collapses all the way down to a black hole. And the most dreaded effect of all that can befall an object venturing too close to a black hole – spaghettification, or being pulled apart into long, thin strands – happens as a result of the incredibly strong tidal effects of the black hole's gravitational field.



HOW DO SATELLITES STAY IN ORBIT?

Many people find it confusing that a satellite can stay in orbit without expending any power – particularly when they're told that this is due to gravity. Surely gravity would just pull the satellite down to Earth? This would be true if it simply remained stationary at an altitude of, say, 200 miles, where gravity is almost as strong as it is down here on the surface of the planet. But the fact is that satellites aren't stationary – they're moving at high speed parallel to the surface of Earth. To understand how this works, it helps to consider what would happen in the absence of gravity. Since there's very little air resistance at that altitude, the satellite would just whiz along in a straight line at constant speed. But because gravity is constantly pulling it towards the centre of Earth, it's bent round in a big circle instead.

GRAVITY TIMELINE

1638

Galileo wrote that different weights fall with the same acceleration, based on the results of practical experiments.

1687

Sir Isaac Newton published a book containing his detailed mathematical theory of gravitation.

1705

Edmond Halley used Newton's theory of gravity to compute the orbit of the comet that bears his name.

1798

Henry Cavendish became the first person to measure the gravitational force between two objects in a laboratory.

1915

Albert Einstein produced a new theory of gravitation, called general relativity. It's still the best theory we have today.

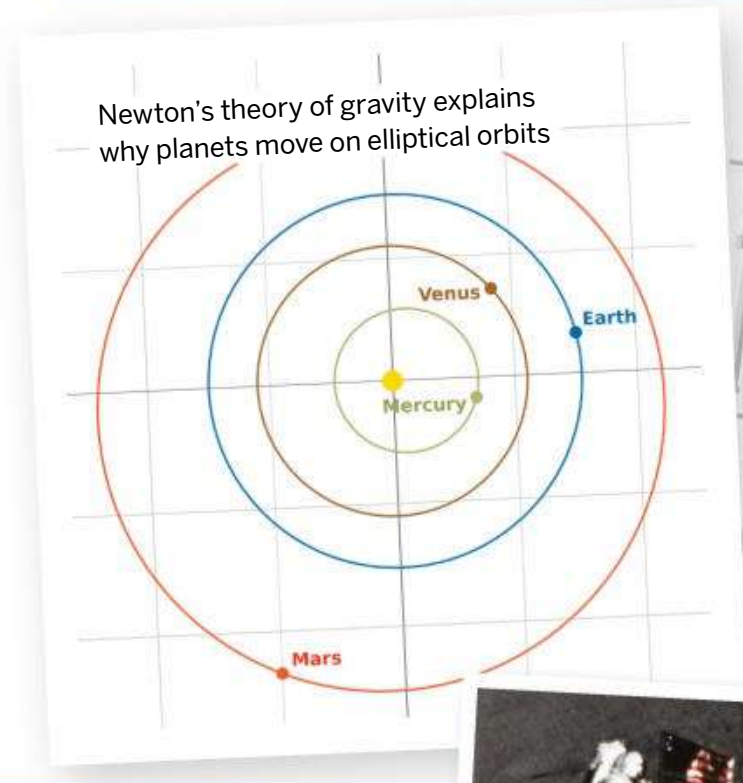
DID YOU KNOW? The gravity of Mars' moon Deimos is so weak you could jump off it and never fall down

WHO DISCOVERED GRAVITY?

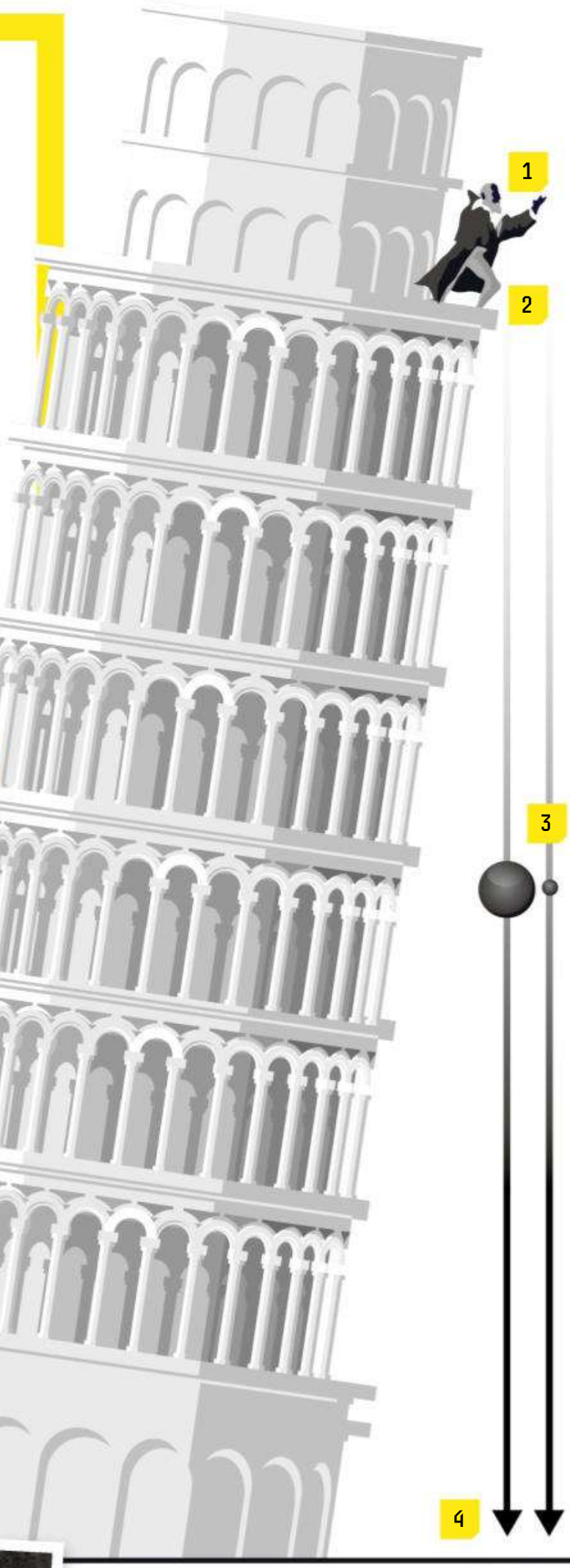
The ancient Greeks believed that gravity was simply a natural tendency of earthly objects to fall towards the ground, whereas celestial objects such as planets obeyed a completely different principle that caused them to move in circles. A proper scientific study of gravity had to wait until the 17th century. Galileo Galilei was the first person to record systematic experiments on the subject, but a few decades later, Isaac Newton went even further. He produced what has become known as his law of universal gravitation, which was a remarkable achievement for two reasons. Firstly, it encapsulated the effects of gravity in the form of a mathematical equation – something that hadn't been done before for a 'force of nature'. Secondly, his formula not only explained everyday gravity here on Earth, but the orbits of astronomical bodies such as the Moon and planets as well.

$$F = G\frac{m_1 m_2}{r^2}$$

Newton's formula involves a constant G, masses m1 and m2 and the distance, r



Newton's theory of gravity explains why planets move on elliptical orbits



The tower began leaning during construction in the 12th century

GALILEO'S GRAVITY EXPERIMENT

Galileo is reputed to have used the Leaning Tower of Pisa for this dramatic demonstration

1 GALILEO
He climbed to the top of the tower, which is roughly 50 metres above the ground.

2 TWO CANNONBALLS
He simultaneously dropped two cannonballs made of different materials, hence having different weights.

3 THE EFFECT OF GRAVITY
Gravity accelerates all objects at exactly the same rate, regardless of their mass.

4 OUTCOME
The balls hit the ground almost simultaneously, which Galileo expected, unlike most people at the time.

1969
Astronauts Neil Armstrong and Buzz Aldrin became the first people to experience the reduced surface gravity of the Moon.

2004
A satellite, Gravity Probe B, succeeded in directly measuring the curvature of space-time in the vicinity of Earth.

1919
Arthur Eddington confirmed Einstein's theory by measuring the gravitational deflection of starlight by the Sun.

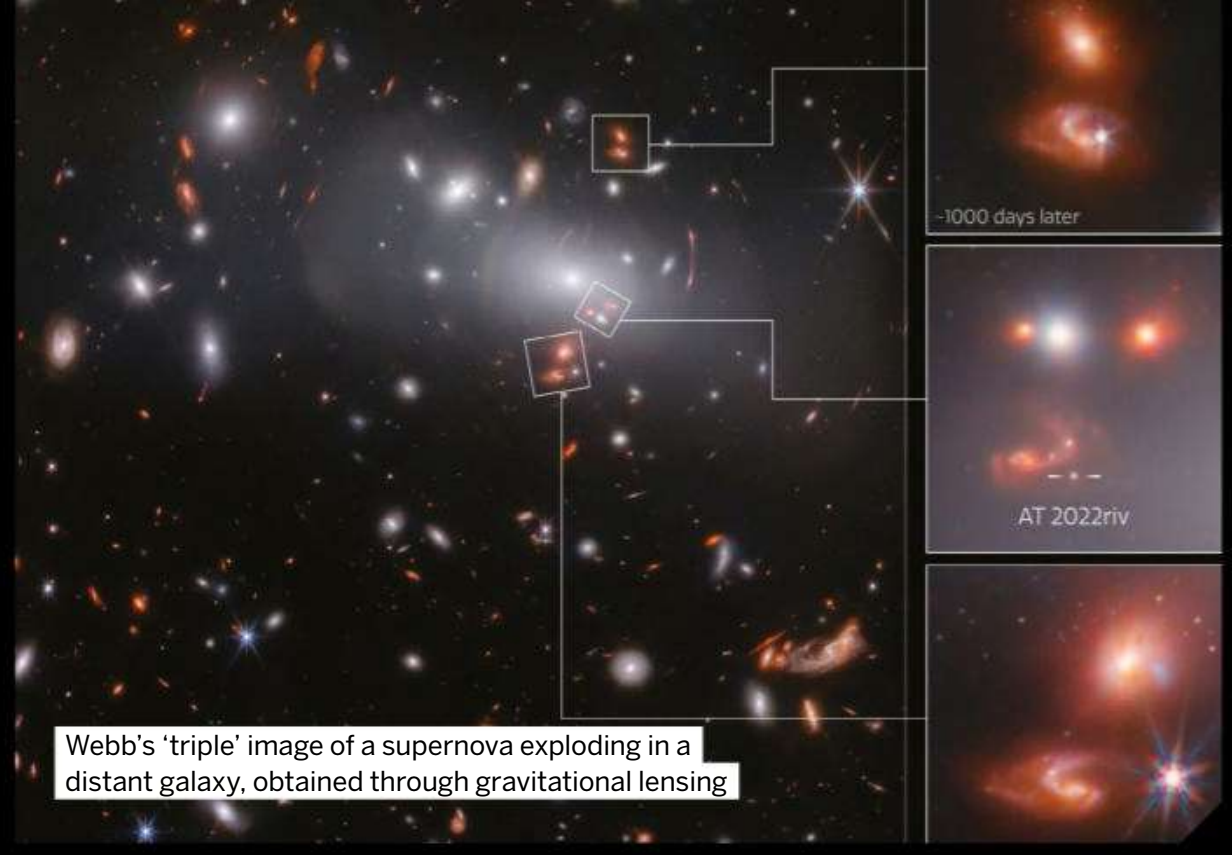
1974
Stephen Hawking produced his seminal research paper on the theory of black holes.

2016
Scientists announced the first detection of gravitational waves, another prediction of Einstein's theory.

© Alamy / NASA / European Southern Observatory

SPECIAL

The merger of two black holes creates gravitational waves that propagate outwards through space-time



Webb's 'triple' image of a supernova exploding in a distant galaxy, obtained through gravitational lensing

GRAVITY ACCORDING TO EINSTEIN

Although Newton's theory of gravity proved good at explaining the vast majority of astronomical observations, it had a major weakness. In 1905, Einstein produced his theory of special relativity, which says that nothing can travel through space faster than the speed of light. In Newton's theory, however, gravity is seen as a force between two objects that is transmitted instantaneously over any distance. For this reason, Einstein realised that a new theory of gravity had to be found that was consistent with his universal speed limit.

One of the revolutionary concepts Einstein had introduced in special relativity was the idea that space and time are woven together into a single fabric, which he called space-time. He used this concept as the basis for his new theory of gravity, which he called general relativity. In this theory, gravity isn't a force that a massive object exerts on another object in the way that Newton imagined. Instead it's a distortion, or 'curvature', of space-time that occurs in the vicinity of a massive object. Any other object moving through this distorted space-time then behaves – in most cases – exactly as it would if a Newtonian-style force was acting on it.

When Einstein published his theory in 1915, there was – believe it or not – just one single astronomical observation that Newton's theory couldn't explain. This related to the orbit of the planet Mercury around the Sun – and Einstein's theory was able to explain the discrepancy perfectly. He was, he said, beside himself with excitement when he realised he had finally solved the mystery of Mercury's orbit.

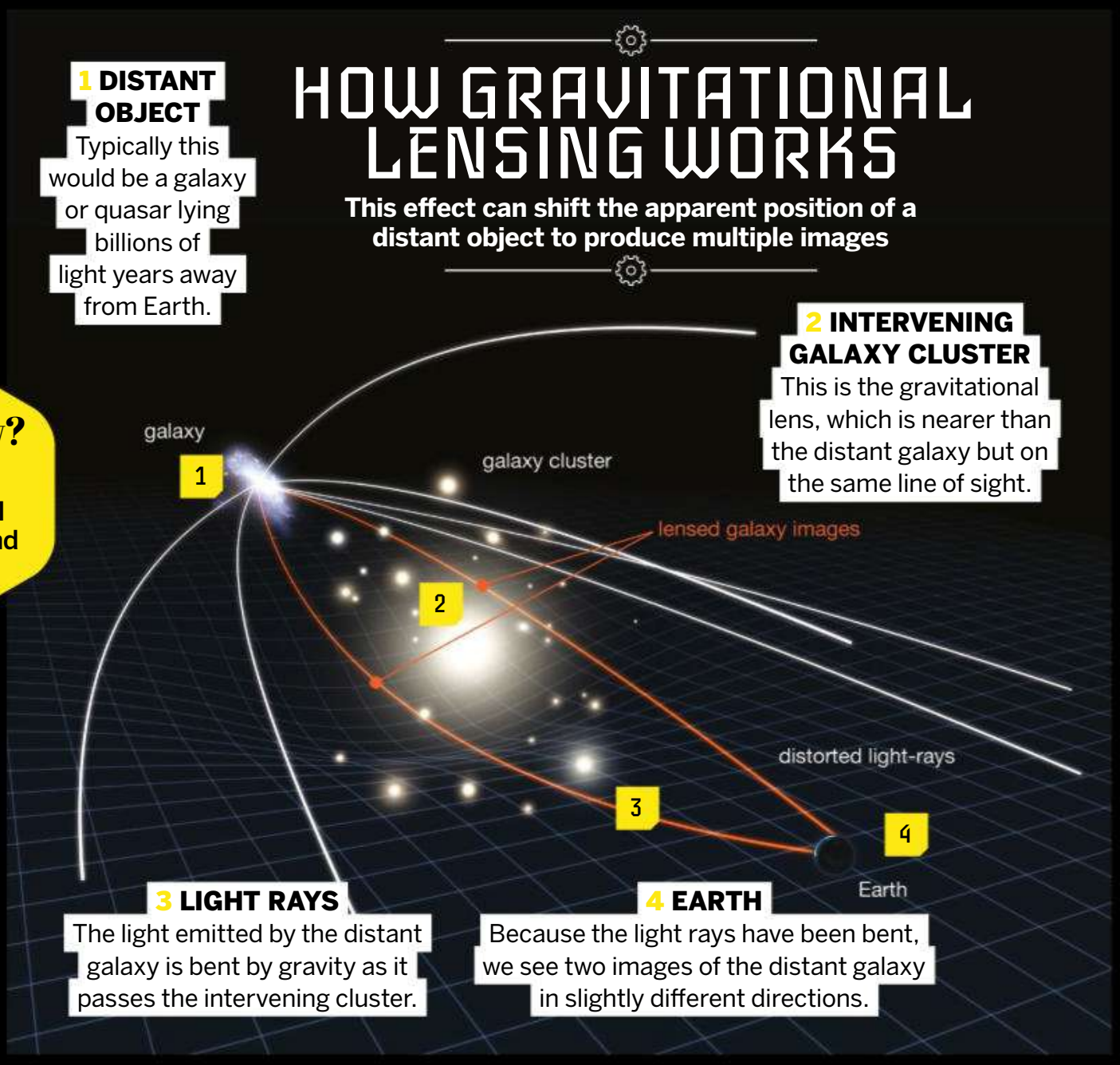
Did you know?

The first gravitational lens was found in 1979

Many other phenomena have been discovered that can only be explained by general relativity, such as the physics of black holes and gravitational waves. At a more mundane level, the GPS software in your smartphone makes use of general relativity, rather than Newtonian theory, in order to calculate your precise position. One of the more obvious consequences of general relativity is that, if space-time itself is warped, then light will no longer travel in a perfectly straight line. It will be bent as it passes around a massive object, following the curvature of space itself. The truth of this was confirmed just four years after Einstein's theory. 1919 saw a total eclipse of the Sun, and a group of astronomers led by Sir Arthur Eddington took the opportunity to observe stars close to the Sun's disc while its light was obscured by the Moon. Eddington's team found that the positions of the stars were shifted by the Sun's gravity by exactly the amount Einstein had predicted.

HOW GRAVITATIONAL LENSING WORKS

This effect can shift the apparent position of a distant object to produce multiple images



1 DISTANT OBJECT
Typically this would be a galaxy or quasar lying billions of light years away from Earth.

2 INTERVENING GALAXY CLUSTER
This is the gravitational lens, which is nearer than the distant galaxy but on the same line of sight.

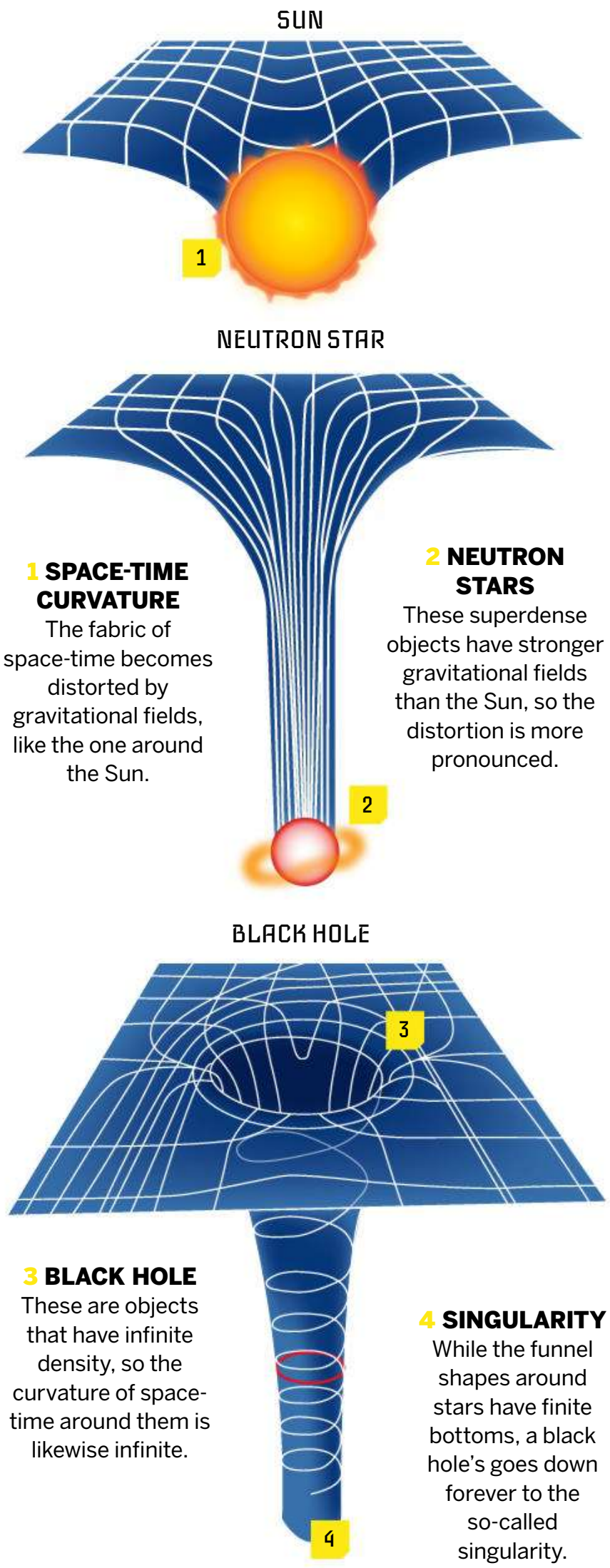
3 LIGHT RAYS
The light emitted by the distant galaxy is bent by gravity as it passes the intervening cluster.

4 EARTH
Because the light rays have been bent, we see two images of the distant galaxy in slightly different directions.

DID YOU KNOW? General relativity may eventually be replaced by an even more complex theory of quantum gravity

BLACK HOLES AND SPACE-TIME

The warping of space-time predicted by Einstein becomes extreme in the case of black holes



1 SPACE-TIME CURVATURE
The fabric of space-time becomes distorted by gravitational fields, like the one around the Sun.

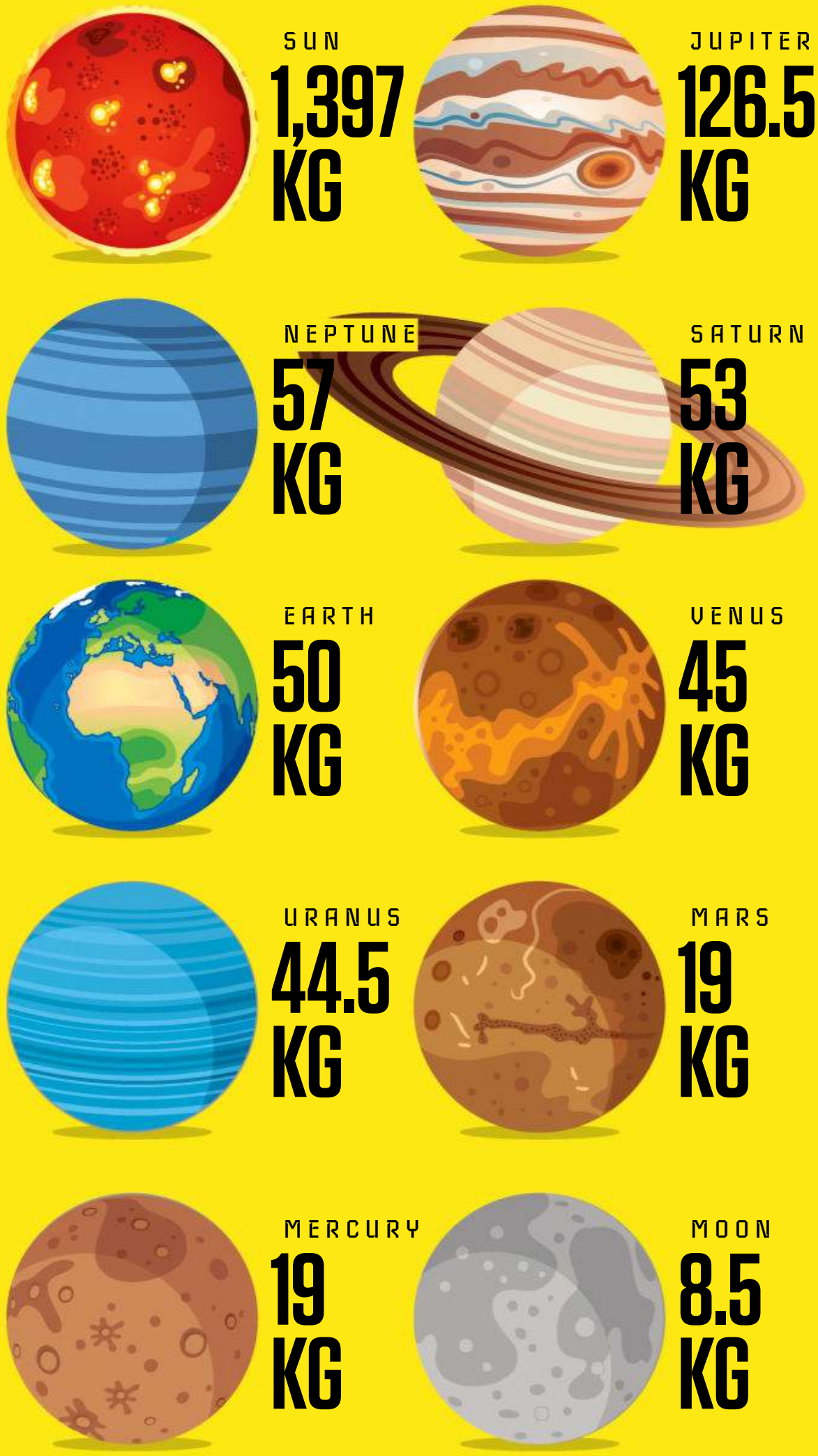
2 NEUTRON STARS
These superdense objects have stronger gravitational fields than the Sun, so the distortion is more pronounced.

3 BLACK HOLE
These are objects that have infinite density, so the curvature of space-time around them is likewise infinite.

4 SINGULARITY
While the funnel shapes around stars have finite bottoms, a black hole's goes down forever to the so-called singularity.

ELSWHERE IN THE SOLAR SYSTEM

What would a 50-kilogram person weigh on the surfaces of other worlds?



© Getty / NASA

SPECIAL

CAN WE MAKE ANTIGRAVITY?

On the face of it, the idea of antigravity isn't that far-fetched. After all, electromagnetism can be either attractive or repulsive, so why not gravity? The obvious answer is that there's only one type of mass – positive – whereas electric charge can be either positive or negative. On the other hand, Einstein's theory of general relativity does lead to electromagnetism-like effects that aren't predicted by simple Newtonian theory. This has led some scientists to investigate whether such effects could produce something that might loosely be termed 'antigravity'.

Back in 1996, Russian scientist Eugene Podkletnov caused a stir when he described an experiment that appeared to demonstrate a way to negate gravity. Unfortunately, other researchers were unable to reproduce or explain his results, which remain controversial to this day. Even so, Podkletnov's intriguing claim was enough to trigger a spate of research projects around the world. The best known was NASA's Breakthrough Propulsion Physics program, which looked at 'gravitomagnetic' devices together with several other advanced technologies. Similar programs on this side of the Atlantic have included Project Greenglow in the UK.

Did you know?

Antimatter has positive mass like ordinary matter

THE 'VOMIT COMET'

An aircraft can simulate the effects of zero-gravity for short periods of time

ZERO G

9,750 METRES

3 PARABOLIC FLIGHT PATH
The aircraft follows a curve called a parabola, similar to the path of a ball thrown at 45 degrees.

4 'WEIGHTLESS' PHASE
As the aircraft free falls down again, the people inside become weightless for up to half a minute.

15

TIME ELAPSED IN SECONDS

0

8,550 METRES

2 STEEP CLIMB
The aircraft starts by climbing upwards at an angle of 45 degrees.

5 STOMACH UPSETS
This is where some unfortunate passengers discover how the aircraft got its nickname.

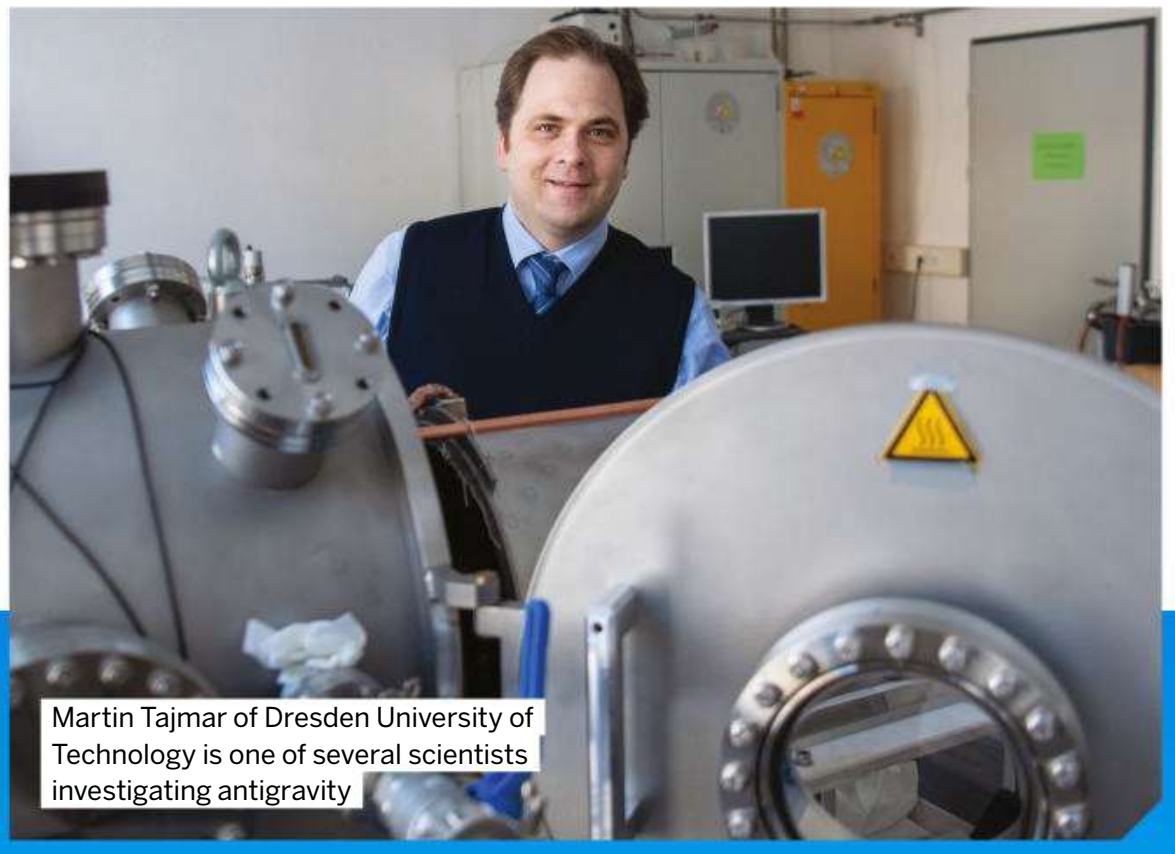
FLIGHT PATH

7,350 METRES

1 FEELING GRAVITY
We only feel gravity if there's something pushing against it, like Earth's surface. We don't feel it when we're falling.

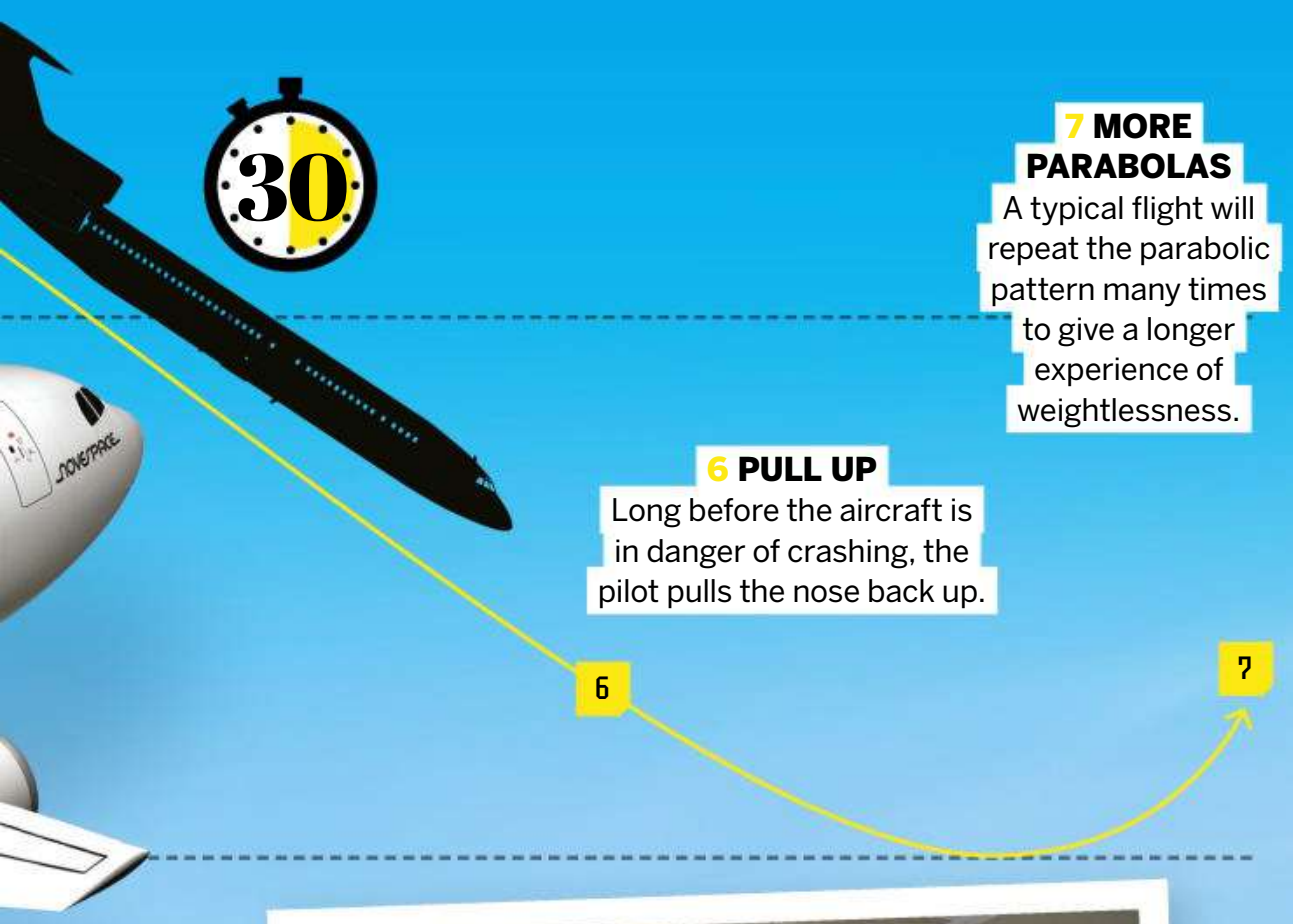
GROUND LEVEL

DID YOU KNOW? A rotating space station would produce an artificial sense of gravity via centrifugal force



Martin Tajmar of Dresden University of Technology is one of several scientists investigating antigravity

"Gravitomagnetism would lead to gravity control"


30
7 MORE PARABOLAS
A typical flight will repeat the parabolic pattern many times to give a longer experience of weightlessness.
6 PULL UP
Long before the aircraft is in danger of crashing, the pilot pulls the nose back up.
6
7

Physicist Stephen Hawking experienced a 'zero-gravity' flight in 2007

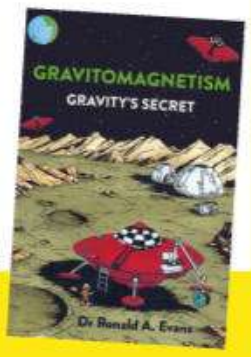
CUTTING-EDGE RESEARCH

We speak to Dr Ron Evans, a leading expert in the field of gravity modification

Why do you feel that antigravity might be a serious possibility?
Rather than 'antigravity', I prefer to think in terms of gravity control. We have a good mathematical model describing the actions of electromagnetism. When we substitute gravity for electricity in the electromagnetic model, the existence of a new force field called gravitomagnetism is predicted. When a gravitomagnetic field changes, a gravity force is generated. To progress we must first be able to detect gravitomagnetism experimentally. Controlling gravitomagnetism would lead to gravity control and the possibility of a new means of mass propulsion.

How do you think it might work?
There are two approaches which seem promising. First, it's thought that gravitomagnetism affects polarised light. If so, fibre optics wrapped around a moving mass may be used to detect the gravitomagnetic field. The next step would be to change the gravitomagnetic field in a controlled manner in order to create a gravity field. An alternative is a quantum approach. In gravitational redshift, a vertical beam of photons change frequency to nullify Earth's gravity. Causing photons to change frequency in some other way may lead to the creation of a gravity field.

What progress have you seen over the years you've been involved in the field?
In the 1990s NASA started its Breakthrough Propulsion Physics program, led by Marc Millis. In the UK, I was involved in BAE Systems' Project Greenglow. The project consisted of a number of gravity-related studies running at several universities. These included experimental investigations of the claim of gravity screening using superconductors, the photon-driven rocket and the Casimir force. Theoretical studies confirmed the gravitational analogue of electromagnetism is a weak-field approximation to Einstein's general relativity. In Europe, advanced space propulsion systems are being investigated by Professor Martin Tajmar of Dresden University.



In his 2022 book *Gravitomagnetism*, Evans discusses one possible route to 'antigravity'

© Ron Evans / NASA / Science Photo Library

SPECIAL

GRAVITY BY NUMBERS

NEWTON WATCHED AN APPLE FALL – IT DIDN'T HIT HIS HEAD

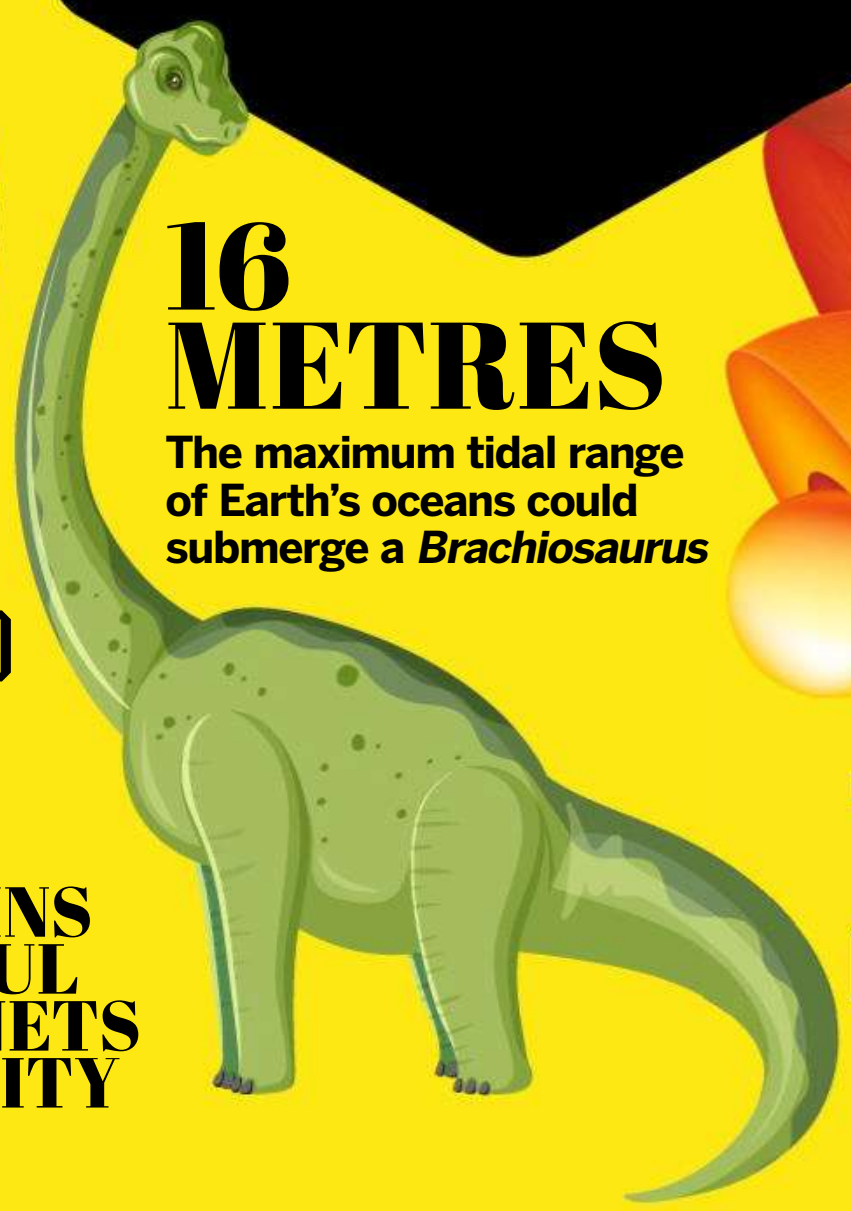
6.8
MILES PER SECOND
Speed needed to escape Earth's gravitational pull

AIRCRAFT DEFY GRAVITY VIA LIFT FROM THEIR WINGS

0.7%
The strength of gravity varies by less than one per cent over Earth's surface

GRAVITY PREVENTS US SEEING THE FAR SIDE OF THE MOON

30 BILLION SUNS
The mass of the most massive known black hole



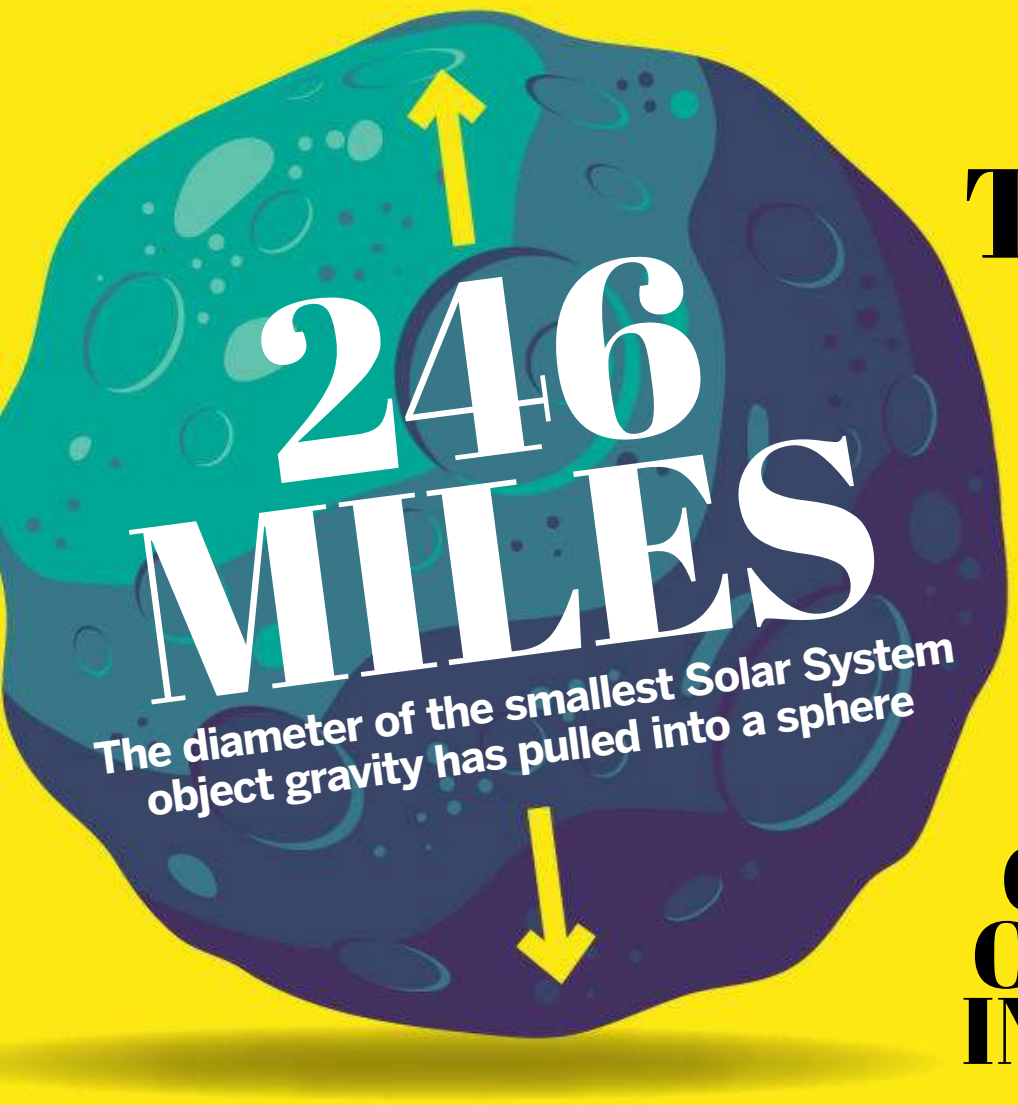
16 METRES
The maximum tidal range of Earth's oceans could submerge a *Brachiosaurus*

9.8 METRES PER SECOND
The rate at which falling objects accelerate in Earth's gravity

ZERO
You'd weigh precisely nothing at the centre of the Earth

MAGLEV TRAINS USE POWERFUL ELECTROMAGNETS TO DEFY GRAVITY

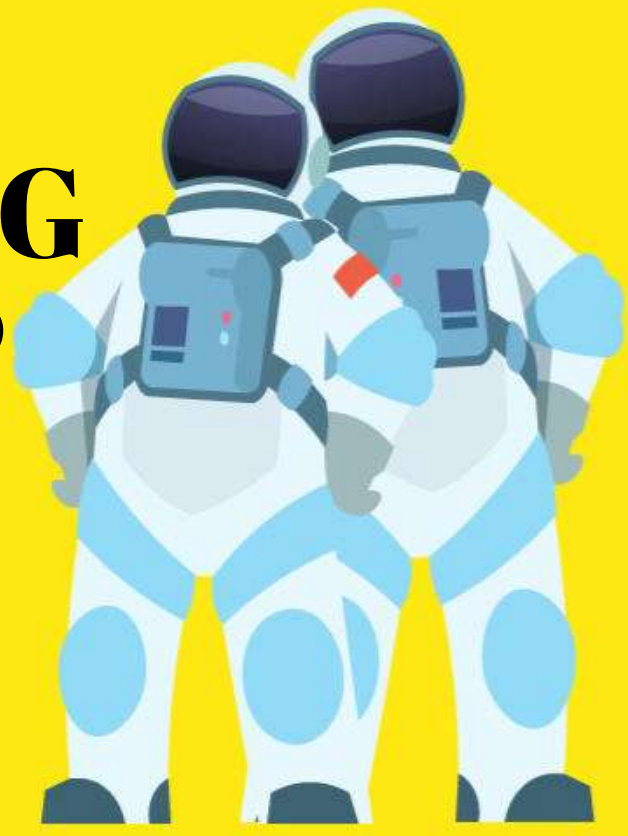
DID YOU KNOW? If two baseballs were put a metre apart in deep space, mutual gravitation would pull them together in three days



246 MILES

The diameter of the smallest Solar System object gravity has pulled into a sphere

LIGHT TRAVELLING UPWARDS AGAINST GRAVITY GETS REDDER



FIVE CENTIMETRES

Astronauts are a little bit taller after living in zero gravity

A FRINGE THEORY SAYS GRAVITY GETS WEAKER AS THE UNIVERSE EXPANDS

OUR THEORY OF GRAVITY IS INCONSISTENT WITH QUANTUM PHYSICS

186,411 MILES PER SECOND

Gravitational effects travel through space as fast as light

GRAVITY COMES FROM THE LATIN GRAVITAS, MEANING' WEIGHT

5

Largest number of images of a single gravitationally lensed quasar

4

Astronauts feel four times heavier during a rocket launch

0.003 DEGREES

The gravity of a mountain has a slight but measurable effect on the swing of a pendulum

© Getty

HOW DIALYSIS MACHINES WORK

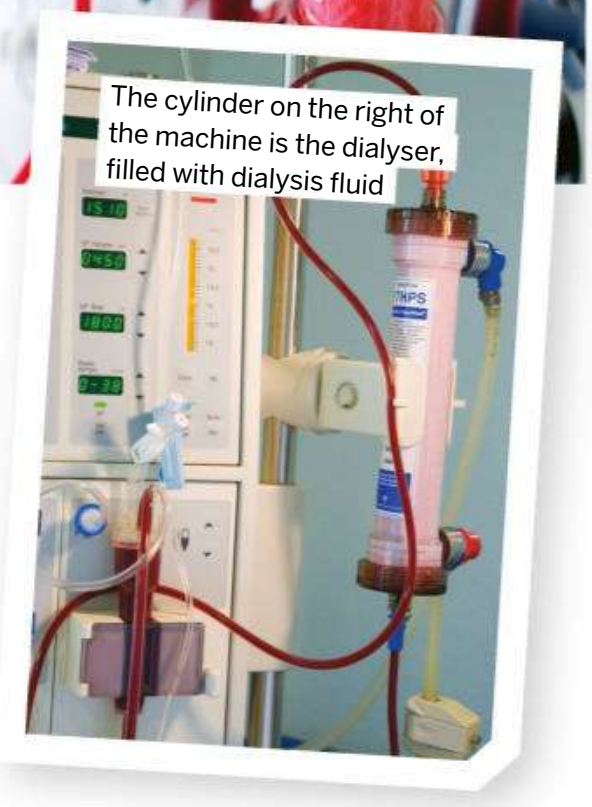
These lifesaving devices take over the role of failing kidneys

WORDS **AILSA HARVEY**

Without healthy kidneys, your body would quickly fill with toxins, causing it to shut down. To prevent this buildup, these two fist-sized organs are continuously working to filter out waste substances from biological processes and pass them out of the body in your urine. For people who suffer from kidney failure, an alternative method is needed to emulate this essential task. Dialysis machines, which were invented in 1943, divert blood out of the body to be cleaned before being returned to the body. Because the body is continually producing waste, patients who depend on dialysis usually undergo four hours of treatment approximately three times a week.

During the process, the machine is attached to a needle, often placed in the arm, through which blood can be extracted and returned. As the blood enters the dialysis machine, it passes along a layer of membranes. These membranes have microscopic holes that only water and waste molecules can filter through. Because of this, no blood cells are lost to the machine – they simply take a diversion on their circulatory course.

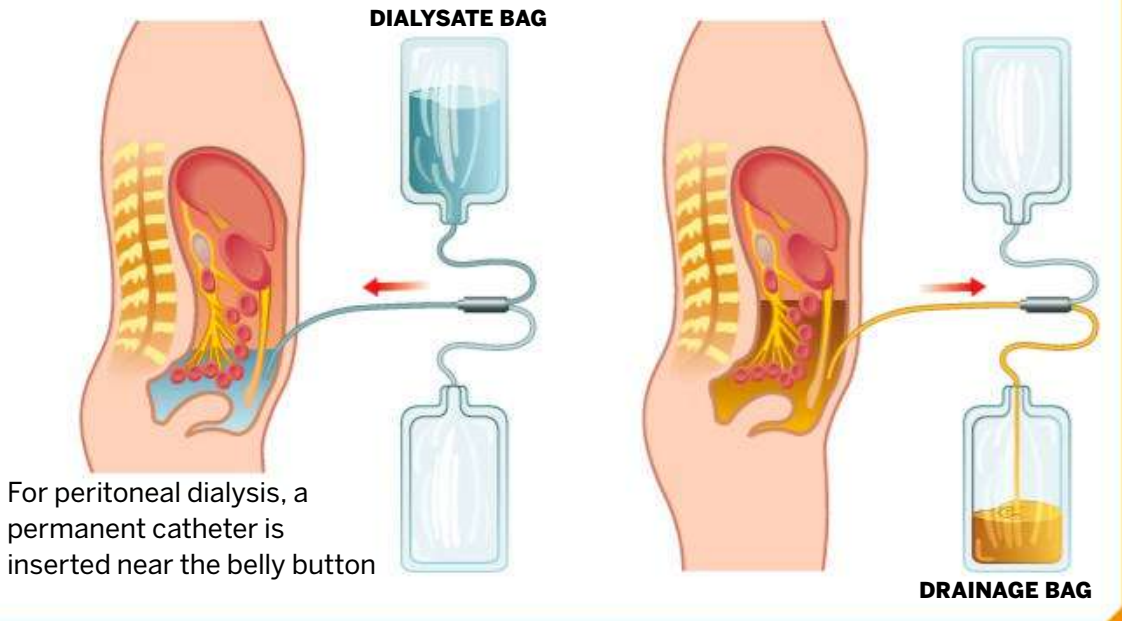
The dialysis machine's fluid, called dialysate, consists of water, electrolytes and salts. Mimicking the concentration of body fluid found outside of your body's cells, dialysate draws waste products across the membrane in a process called diffusion. Because the waste molecules are in higher concentrations in the blood, they pass from an area of high concentration to an area of low concentration. When the blood is returned to the vein, it's in a similar condition to filtered blood that has passed through the kidneys.



The cylinder on the right of the machine is the dialyser, filled with dialysis fluid

INSIDE AND OUTSIDE THE BODY

There are two types of dialysis: haemodialysis and peritoneal. The former involves an external dialysis machine, while peritoneal dialysis takes place mostly inside the body. Dialysis fluid is pumped into a space in the abdomen known as the peritoneal cavity, and the membrane lining the abdomen carries out the usual role of the kidneys. Waste products diffuse out of the blood and into the abdominal cavity, ready to be pumped back out of the catheter tube into a separate bag. This form of dialysis is ideal for people who need regular treatment and want to fit it around their busy schedules. Instead of clocking significant hours in hospital while hooked up to a haemodialysis machine, portable peritoneal dialysis machines can be used at home or while travelling.

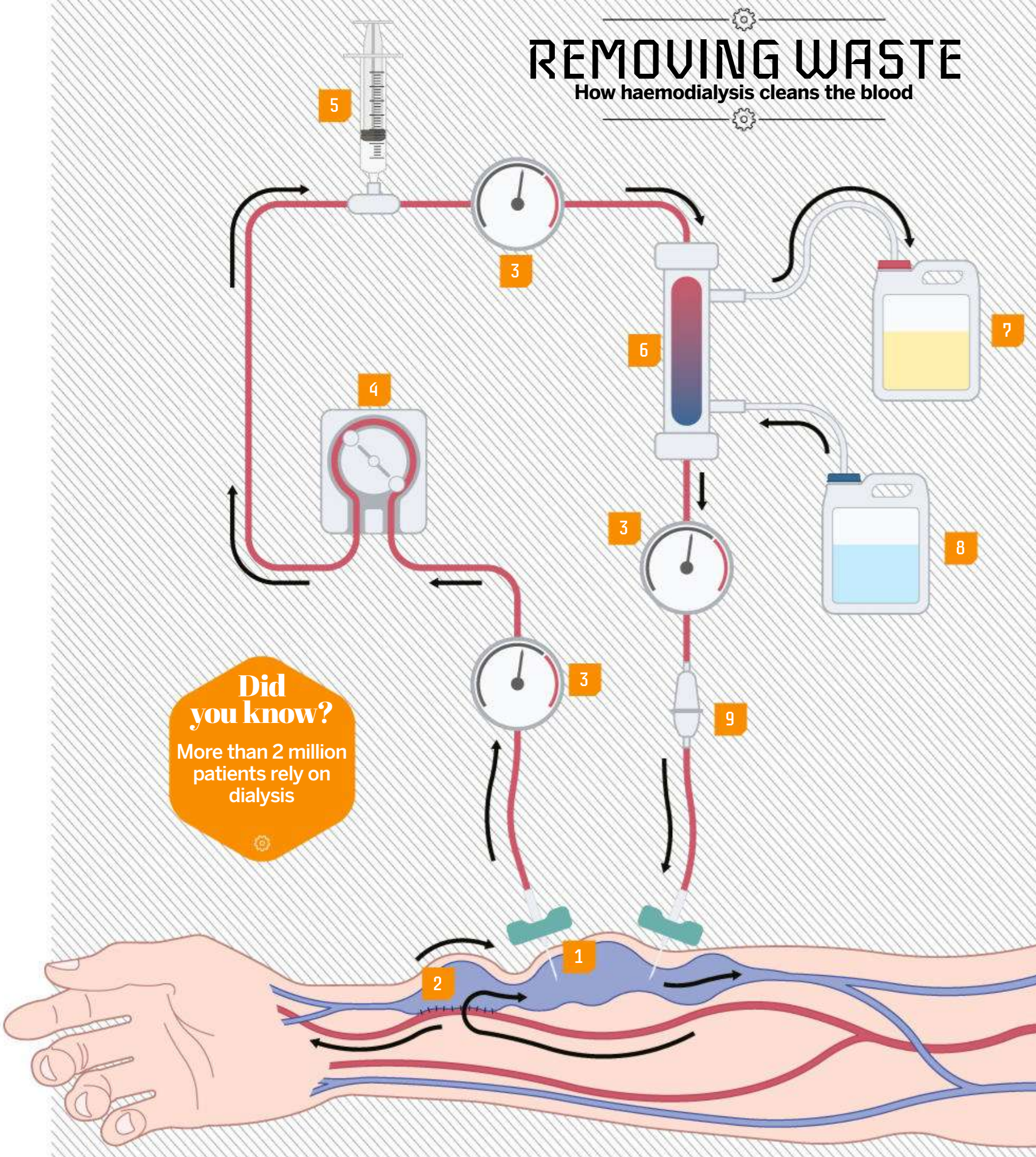


For peritoneal dialysis, a permanent catheter is inserted near the belly button

DID YOU KNOW? Around ten per cent of the world's population suffers from chronic kidney disease

REMOVING WASTE

How haemodialysis cleans the blood



Did you know?

More than 2 million patients rely on dialysis

5 FACTS REASONS FOR DIALYSIS

1 DIABETES
Diabetes is a condition that can lead to high blood sugar. Over time this can cause damage to the kidneys' blood vessels, preventing the organs from working well.

2 HYPERTENSION
High blood pressure causes blood vessels in the kidneys to narrow, weakening them over time and reducing the kidneys' function.

3 INFLAMMATION
Infections can cause inflammation of the kidneys. Inflamed kidneys leak proteins into urine, stopping it from absorbing water from body tissues.

4 CYSTS
When fluid-filled sacs form in the kidneys, the membranes they protrude from are unable to filter waste from the blood.

5 INHERITED DISEASE
There are around 300 genetic kidney disorders. Some of these conditions require the use of dialysis machines.

1 CATHETER
A tube is inserted into a large vein in either the leg, arm or chest.

2 ARTERIOVENOUS FISTULA
A surgeon carries out a procedure to connect an artery and vein together. This creates a strong site for dialysis.

3 PRESSURE MONITORS
When too much fluid is removed from the blood, patients can suffer from low blood pressure. This monitor sounds an alarm when this occurs.

4 BLOOD PUMP
This device drives blood around the dialysis machine when outside the body, directing blood out of and back into the body.

5 HEPARIN PUMP
A blood-thinning medication called heparin is added to the blood through a syringe. Heparin prevents the blood from clotting when outside the body.

6 DIALYSER
Membranes in the main machine filter waste products out of the blood, but keep blood cells separate from the dialysis fluid.

7 WASTE DIALYSIS FLUID
Waste drains out of the blood, through a membrane, into a bag.

8 CLEAN DIALYSIS FLUID
Fresh dialysis fluid is pumped in the opposite direction of the blood flowing through the machine.

9 AIR TRAP
This device detects any air in the blood and prevents it from passing into the body.

© Alamy / Getty / Shutterstock

POLICE TECHNOLOGY EXPLAINED

How personal defence gadgets, tactical weapons and speedy smart vehicles assist those enforcing the law

WORDS AILSA HARVEY

DID YOU KNOW? Between 31 March 2021 and 31 March 2022, there were 18,259 police firearm operations in England and Wales

In police departments all over the world, officers need to be prepared for any emergency. Whether it involves suiting up in armour to tackle rioting mobs, safely alerting road users of diversions or launching into a high-speed car chase, the latest developments in all necessary equipment need to be available. In almost every stage of attending to a case, a police officer will rely on specially designed technology to make their evidence, arrests and convictions as fair as possible.

Police officers can't be everywhere at once. Before cameras were invented and made readily available, arrests could only be made by the luck of an observation or through word of mouth alone. Today, permanent surveillance cameras on city streets and roads make it more difficult for criminals to get away with their nefarious acts. And now the number of police drones being deployed to record activity in criminal hotspots is on the rise too.

Even if a criminal isn't spotted at the scene of a crime or has made a swift getaway, biometric databases make multiple offenders easier to track down. Fingerprints and DNA samples are analysed by forensic teams, while facial recognition cameras can alert police departments when a wanted individual passes by any security camera.

Modern policing technology is making communities around the world safer in many ways, but what does the future of policing look like? Find out about some of the technological devices officers have on-hand and explore the early developments of artificial intelligence and robotics that could soon serve a more significant role in police forces.

CARRYING FIREARMS

In the US, Australia, many European countries and most African countries, police officers carry firearms. Meanwhile, in the UK, most officers do not. Firearms are instead restricted to specifically trained police officers with the title of authorised firearms officer (AFO). AFOs are called to duties that are classed as high-risk – some involve the military, or large-scale events to reassure the public of their safety if an emergency were to occur. Only about five per cent of all police officers in England and Wales are authorised to use guns.

Most US police officers carry a handgun such as the Glock 22

UNIFORM BREAKDOWN

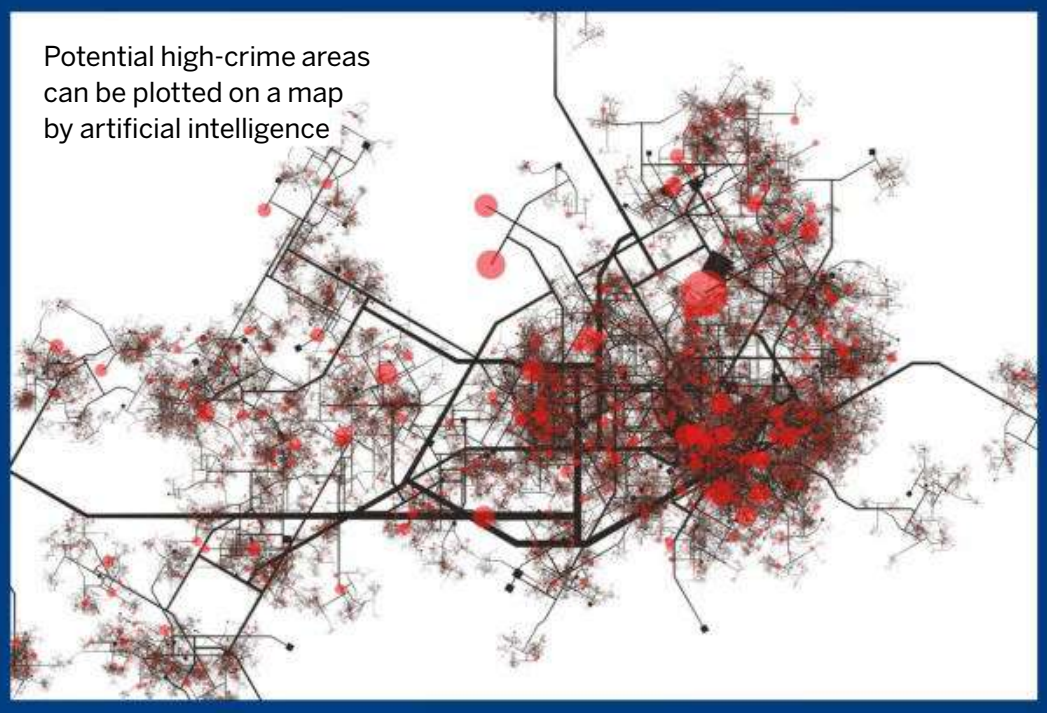
What equipment does an officer wear and carry on patrol?

2 RADIO
Officers communicate with each other and call for backup using personal radios.
3 BODY CAMERA
Small cameras on the uniform constantly record video and audio evidence during police interactions.
1 DUTY JACKET
Police officers wear a jacket with multiple pockets to carry an array of equipment.
5 BATON
An extendable baton can be drawn and used as a defense against non-compliant individuals.
4 HANDCUFFS
This pocket contains handcuffs for use when restraining and arresting individuals.
6 PEPPER SPRAY
Inside this pocket is a spray containing an inflammatory compound called capsaicin. Derived from chilli peppers, it makes a person's eyes feel like they're burning. Police use this to stop a criminal from seeing temporarily so the police can arrest them.
POLICE

Did you know?

The first metal handcuffs were one size fits all

© Alamy



Potential high-crime areas can be plotted on a map by artificial intelligence

PREDICTING HOTSPOTS

Criminals can be dangerous and are somewhat unpredictable – or are they? With advancements in computer technology in the last ten years, police officers no longer have to wait around for criminal activity to take place. Instead they can use artificial intelligence to analyse criminal records and detect patterns in when, where and how crimes are committed.

Algorithms designed by a research team at the University of Chicago were tested for reliability by presenting the computer with data about crimes in Chicago between 2014 and 2016. The predictive model highlighted which areas of the city were most likely to experience crime in the following few weeks, with a reliability of 90 per cent.

Throwable police cameras are usually covered in thick rubber to protect the components inside

THROWABLE ROBOT SPIES

As part of their role on the front line, most police officers are familiar with entering high-risk zones and invading suspicious scenes to investigate. By barging down doors and placing themselves into unknown areas, officers make extra effort to uncover the truth about what's going on behind closed doors. One piece of technology that can take the place of a police officer, sneaking into small places and using its six cameras to relay real-time images, is the Tactical Explorer. This is a rubber-coated throwable camera ball. Before entering a room, an officer can throw this ball through the door or window to get a 360-degree view of what, or who, is inside the room via a connected smart device. Knowing the whereabouts of danger before physically entering a room means that officers are less likely to be taken by surprise.

HOW POLICE TASER GUNS WORK

Tasers deliver an electric shock to criminals, causing their muscles to contract and bringing them to the floor

1 GENERATOR
Here an electric current is produced with an output up to 50,000 volts, but only 1,200 volts is delivered to a person's body.

2 COMPRESSED NITROGEN
When the trigger is pressed down on the taser, nitrogen gas is released from this high-pressure container. As nitrogen escapes, it pushes the probes out from the gun.

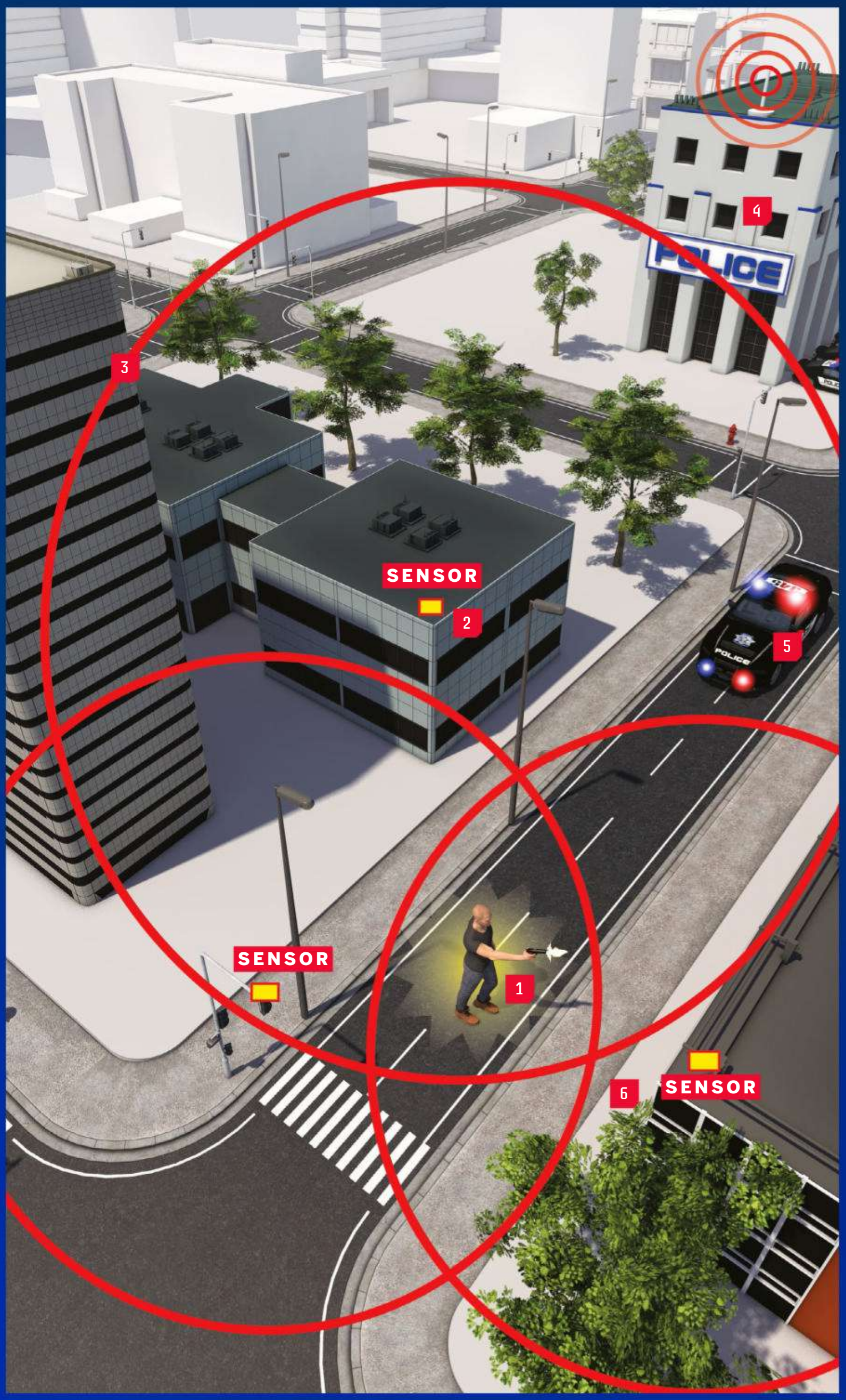
3 IDENTIFICATION TAGS
20 to 30 confetti-like tags are released from the taser when it's fired. These are ID tags with the weapon's serial number on to show the owner of the fired gun.

4 CARTRIDGE DOORS
The panels that cover the end of the gun to protect internal components are blasted off as nitrogen is released.

5 FIRED PROBES
Two probes pierce the target's clothes and make contact with their skin. This relays an electric current into their body at 19 pulses per second.

6 CONNECTED CIRCUIT
The probes remain connected to the gun's electricity generator via thin wires. These are around ten metres long.

DID YOU KNOW? Some tasers have small cameras that record when the trigger is pressed, ensuring the gun's use is justified



TRACING A GUNSHOT

ShotSpotter is a network of city sensors that can pinpoint the location of a gunshot by its sound

1 GUNFIRE SOUNDS
Sensors installed around a city are programmed to respond to the distinctive sound of gunfire.

2 SENSOR DETECTION
At least three sensors, attached to the top of streetlights, buildings and other objects, record the audio.

3 LOCATION ANALYSIS
The combined audio data –including the distance and direction of the sound from each sensor – is analysed, and a location is sent to the local police department within 45 seconds.

4 POLICE ALERT
At the police station, acoustic experts confirm whether the recorded audio was produced by gunfire and the type of weapon used.

5 POLICE DEPLOYMENT
Knowing the location of the shooter, police respond to the incident efficiently.

6 WIDESPREAD INSTALLATION
ShotSpotter sensors are set up in more than 130 cities in the US.

Did you know?

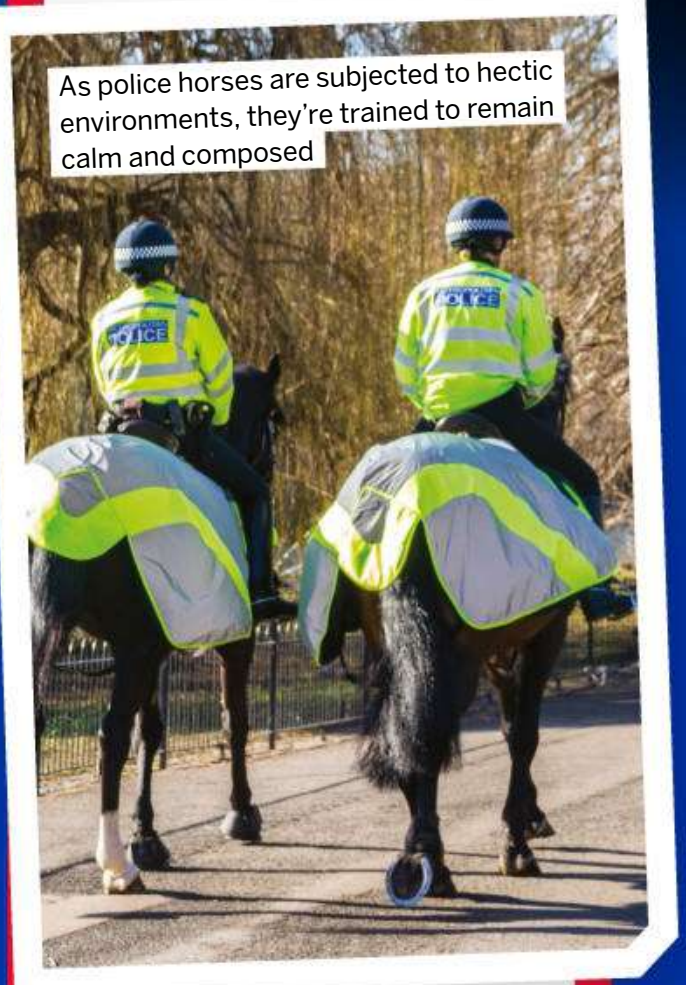
SoundThinking's ShotSpotter sensors are 97 per cent accurate

© Getty / Alamy / Illustration by Adrian Mann

ALTERNATIVE TRANSPORT

Police assistance isn't just required on roads. So what happens when police need to race to the centre of a large pedestrian park or need to see over the heads of huge crowds at large-scale events? Police officers use a range of transportation methods, from bikes and motorbikes to the less common horseback, Segways and quad bikes.

Horses were a go-to transport method for police officers before motorised vehicles were commonplace, but today they are saved for specific events. These include search-and-rescue operations, where the highly mobile animals can traverse through tight spaces, and events with great crowds that demand sight from a higher vantage point. Segways are sometimes provided to on-foot patrollers when an increase in speed or prolonged energy levels may be needed. Finally, the number of police quad bikes in the UK is on the rise as officers aim to tackle antisocial behaviour in rural areas, where illegal off-road vehicles are sometimes driven.



As police horses are subjected to hectic environments, they're trained to remain calm and composed

CAR CHARACTERISTICS

For detailed surveillance, speedy transportation and high-speed chases

RADIATION DETECTOR
This small device constantly monitors the level, cause and type of radiation present in the air.

SIRENS
The piercing sound of a police siren alerts all drivers to a police car's presence. There are three different siren patterns with varying pitches so that multiple vehicles aren't mistaken for just one.

NUMBER PLATE RECOGNITION
Cameras automatically scan car number plates on the road. If a car is linked to crime on the police database, the police vehicle's dashboard displays an alert.

REAR-SEAT RECORDING
From when a criminal is arrested and seated in the back of the police car to when they are placed in jail, all of their actions and words are recorded as part of police evidence.

LIGHTS
Flashing red lights indicate a hazard to alert drivers of an incident and that they need to drive with caution. Blue lights are slightly easier to see from a distance in the dark, making the colour combination unmissable at all hours.

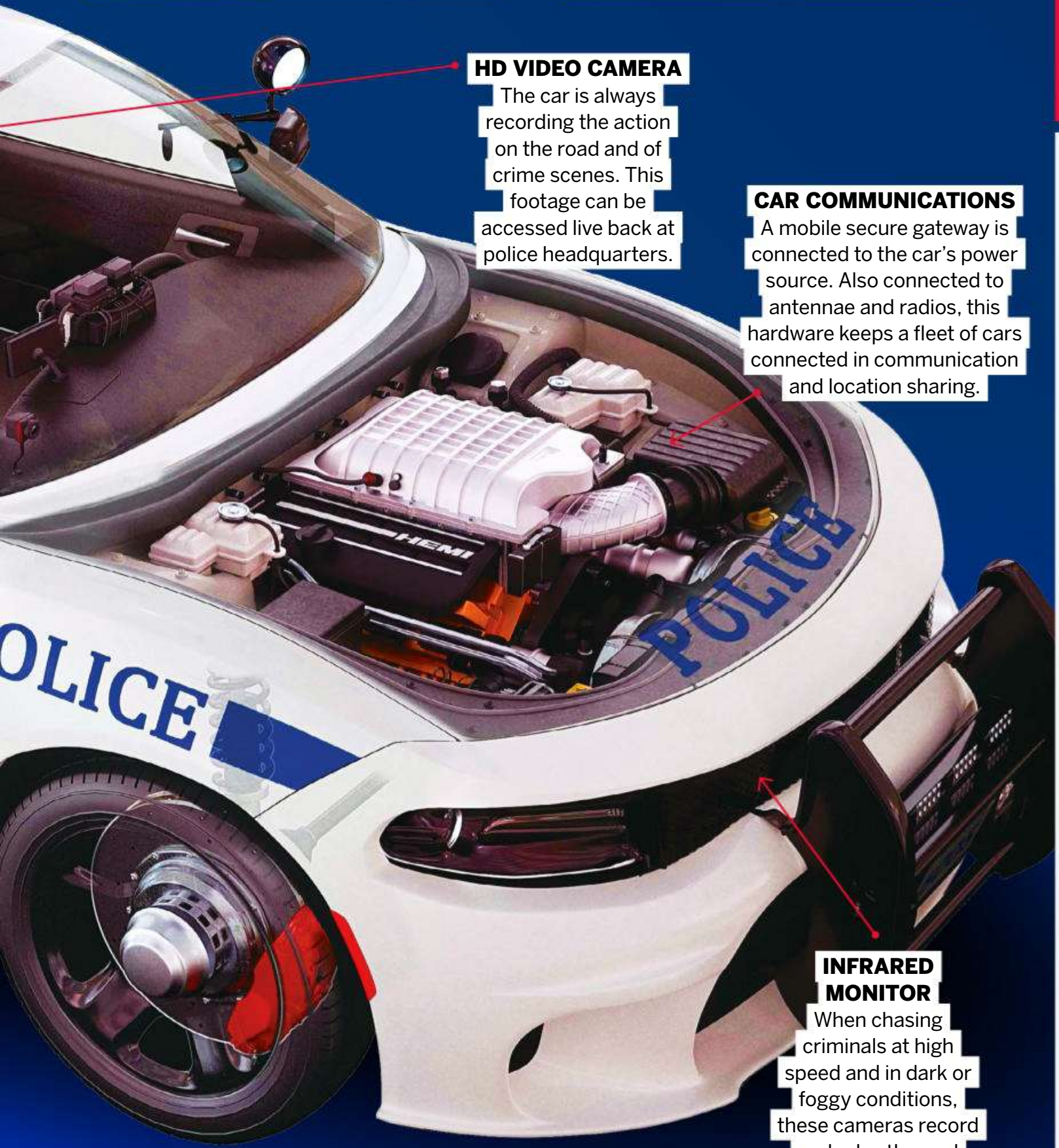
DID YOU KNOW? The Ford Focus, Vauxhall Astra and Vauxhall Insignia are the most common police car models in the UK

Bikes help with patrolling parks

Undercover operations use an unmarked car

Did you know?

A police horse undergoes around two years of training



HD VIDEO CAMERA
The car is always recording the action on the road and of crime scenes. This footage can be accessed live back at police headquarters.

CAR COMMUNICATIONS
A mobile secure gateway is connected to the car's power source. Also connected to antennae and radios, this hardware keeps a fleet of cars connected in communication and location sharing.

INFRARED MONITOR
When chasing criminals at high speed and in dark or foggy conditions, these cameras record and relay thermal heat imagery to the driver to make following the target easier and safer.

5 TYPES OF POLICE VEHICLE

1 PURSUIT VEHICLES
The main role of a pursuit vehicle is to respond to emergency situations quickly after police headquarters receive a call.

2 PADDYWAGON
This is a larger van or truck that's used to transport multiple people who have been arrested or groups of prisoners.

3 SUVS
These vehicles are mainly used to carry gear and assist the patrol and pursuit cars at a scene.

4 UNMARKED CARS
These undercover police cars have removable sirens and no police graphics on their body. In these vehicles, police can assess criminal activity while maintaining a low profile.

5 ARMOURED VEHICLES
For the riskiest incidents, such as those involving firearms, armoured vehicles are deployed to turn the vehicle into a refuge zone.

© Alamy / Illustration by Nicholas Forder

WHERE DOES YOUR POO GO?

Following the flush, your body's waste undergoes a long journey as it's prepped to return safely to the environment

WORDS **AILSA HARVEY**

Thanks to an efficient and complex network of underground pipes, tunnels and high-tech wastewater treatment plants, the journey of your poo after you flush is usually out of sight and out of mind. However, with a population of 8 billion people, and with each adult producing an average of 145 kilograms of faeces every year, the safe disposal of masses of human waste is essential. Your faeces are a combination of undigested food – such as insoluble fibre that's difficult for the body to break down – mucus, bacteria, water and cells from the lining of your intestines. Per gram of faeces, there are 100 billion bacteria. This number changes per person and increases drastically when a person is suffering from an infection. Our bodies often flush out infections through human waste, and so without separating and thoroughly treating sewage, faeces hold great potential to spread disease in communities and the environment.

DID YOU KNOW? Modern toilets use around six litres of water every time you flush

FLUSHING PHYSICS

How toilets flush and refill while serving as a barrier between your bathroom and the sewer

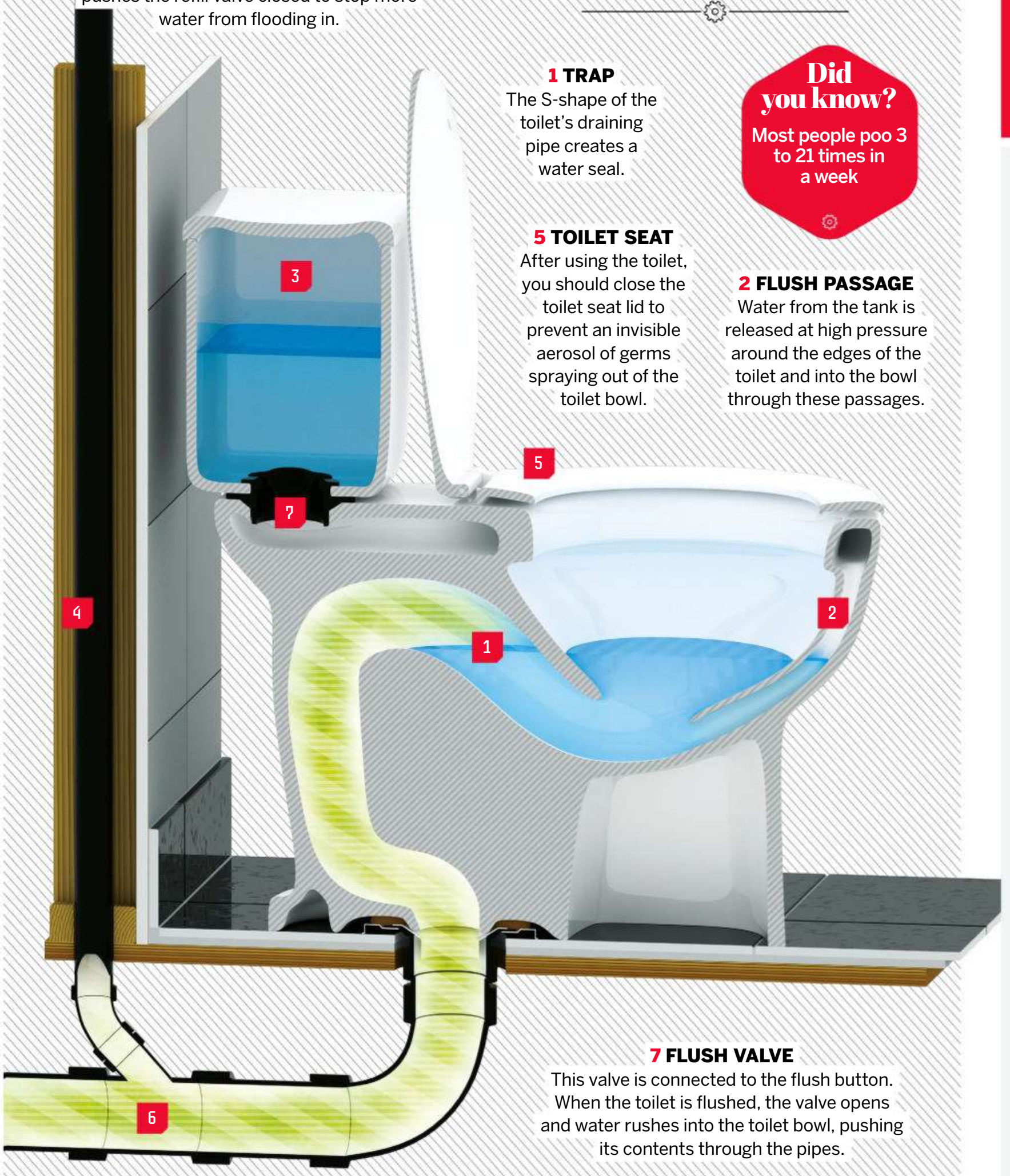
3 WATER TANK
Water from the building's water supply is released into this tank. A floating device rises with the water and when reaching the top, pushes the refill valve closed to stop more water from flooding in.

1 TRAP
The S-shape of the toilet's draining pipe creates a water seal.

Did you know?
Most people poo 3 to 21 times in a week

5 TOILET SEAT
After using the toilet, you should close the toilet seat lid to prevent an invisible aerosol of germs spraying out of the toilet bowl.

2 FLUSH PASSAGE
Water from the tank is released at high pressure around the edges of the toilet and into the bowl through these passages.



7 FLUSH VALVE
This valve is connected to the flush button. When the toilet is flushed, the valve opens and water rushes into the toilet bowl, pushing its contents through the pipes.

6 SEWAGE PIPE
This pipe carries flushed waste to sewers. The sewer gas in the pipe rises, but can't travel up the S-shape of the pipe's trap.

4 ROOF VENT
This pipe extends all the way to the top of the building's roof. This is an outlet for sewer gas so that it doesn't build up in the pipes.

5 TYPES OF TOILET

1 LONG DROP
Also known as a pit latrine, this toilet is a large hole in the ground with a small opening covered by a toilet seat. Bacteria in the ground gradually break down the waste. This toilet needs to be at least 50 metres from public areas and far from water sources.

2 GRAVITY FLUSH
When the flush is pushed on these toilets, a valve opens and the toilet's water and waste fall down the pipe due to gravity.

3 PRESSURE ASSISTED
In these systems, additional pressure is added to the work of gravity. A smaller tank inside the main tank traps and compresses air. When it's forced into the bowl during flushing, waste is moved by both the push of air and pull of gravity.

4 COMPOSTING
In a large chamber under these toilets is sawdust and other organic matter such as leaves. These add carbon and air pockets to help microbes decompose the waste naturally. A vent diverts the smell away from the toilet.

5 PORTABLE
These small cubicles can be transported between locations and are placed outside. Waste is sucked from the toilets through a large vacuum device and into containers, which are transported to a wastewater treatment plant.

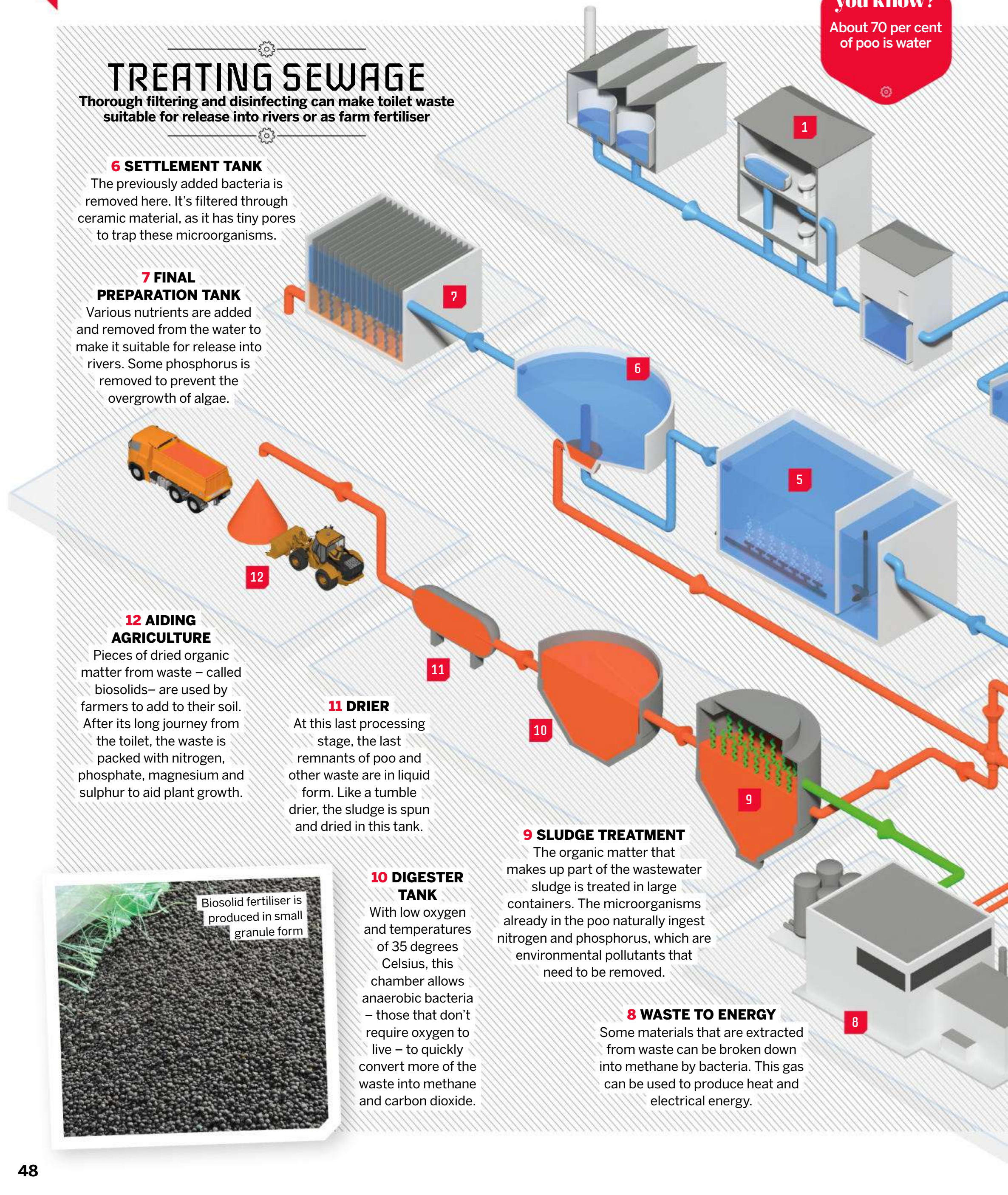
© Getty / Shutterstock

TREATING SEWAGE

Thorough filtering and disinfecting can make toilet waste suitable for release into rivers or as farm fertiliser

Did you know?

About 70 per cent of poo is water



6 SETTLEMENT TANK
The previously added bacteria is removed here. It's filtered through ceramic material, as it has tiny pores to trap these microorganisms.

7 FINAL PREPARATION TANK
Various nutrients are added and removed from the water to make it suitable for release into rivers. Some phosphorus is removed to prevent the overgrowth of algae.

12 AIDING AGRICULTURE
Pieces of dried organic matter from waste – called biosolids– are used by farmers to add to their soil. After its long journey from the toilet, the waste is packed with nitrogen, phosphate, magnesium and sulphur to aid plant growth.

11 DRIER
At this last processing stage, the last remnants of poo and other waste are in liquid form. Like a tumble drier, the sludge is spun and dried in this tank.

9 SLUDGE TREATMENT
The organic matter that makes up part of the wastewater sludge is treated in large containers. The microorganisms already in the poo naturally ingest nitrogen and phosphorus, which are environmental pollutants that need to be removed.

Biosolid fertiliser is produced in small granule form

10 DIGESTER TANK
With low oxygen and temperatures of 35 degrees Celsius, this chamber allows anaerobic bacteria – those that don't require oxygen to live – to quickly convert more of the waste into methane and carbon dioxide.

8 WASTE TO ENERGY
Some materials that are extracted from waste can be broken down into methane by bacteria. This gas can be used to produce heat and electrical energy.

DID YOU KNOW? The Blue Plains wastewater treatment facility treats over a billion litres per day

1 TOILET FLUSH
On average, each person flushes a toilet five times a day. The contents of these toilets are sent through large pipes called sewers.

Sewage treatment plants treat an average of 13.6 million litres of wastewater in one day

2 SCREENS
When the wastewater from all the local area's toilets, sinks and drains has combined in large pipes, it's ready to be treated. First, large screens with small gaps filter out the largest objects in the sewage, which are washed and sent to landfills.

3 GRIT CHAMBER
In this chamber, the movement of wastewater slows so that heavier particles can sink to the bottom. This includes food waste and sand.

4 PRIMARY TREATMENT TANK
Sewage spreads out into this large tank, causing it to still. Fatty molecules float to the surface. Two blades run across the top and bottom of the tank to remove heavy solid organic material from the bottom and light material from the surface.

5 BIOLOGICAL TREATMENT TANK
Billions of bacteria are added to the tank to break down the dissolved materials. Oxygen bubbles up from the bottom of the tank to speed up the bacteria biodegrading the waste.

Toilets on the space station have small toilet bowls to ensure there are no gaps

SPACE TOILETS

How do astronauts go to the toilet, and what happens to their waste? The answer is a vacuum toilet. This specialised toilet is surrounded by handles for the hands and feet to stop astronauts from floating away from the toilet while they do their business. As soon as the lid is lifted from a vacuum toilet, the suction begins right away. This pulls the waste straight down. However, in space there isn't a complex sewerage system connected to each toilet bowl like on Earth. Instead, the poo is vacuumed into bags and stored in airtight containers. This is released into space to burn with reentry into the atmosphere, or in some instances is returned to Earth by spacecraft to be studied by scientists in laboratories.

REDUCING WASTE

Despite poo holding the potential to contribute to agriculture and energy generation, the large majority of it ends up being buried underground after treatment. In these landfills, biosolid sludge eventually decomposes, releasing greenhouse gases into the atmosphere. To prevent these landfills from contributing to global warming through their gas emissions, some companies are working to find creative alternative uses for biosolids. One group of researchers in Australia has come up with a method to make building bricks from dried human waste. Only a quarter of each brick contains treated faeces to keep them structurally strong.

Before entering landfills, this is what dry sewage sludge looks like

© Getty / Alamy

THE WORLD'S FARTHEST LEANING TOWER

Abu Dhabi's Capital Gate leans at more of an angle than Pisa's famous landmark

WORDS **ALEX DALE**

The 160-metre-high Capital Gate is one of the tallest buildings in the United Arab Emirates and is sometimes referred to as the 'Leaning Tower of Abu Dhabi' in reference to Pisa's famous slanting tower. However, with a remarkable incline of 18 degrees, it's the world's furthest leaning human-made tower, with an angle over four times that of Pisa's. The building's overhang – 54 metres from top to base – is possible due to its pre-cambered base. This means it was built leaning slightly in the opposite direction, and as the weight of the floors were added during construction, the core was gradually straightened.

COMPRESSED CORE
The core, which runs through the centre of the building, comprises 15,000 cubic metres of cement, reinforced with over 9,000 tonnes of steel. As the building went up around it, the core was straightened, compressing the cement at the bottom and making the structure stronger.

SUNBLOCK
A stainless-steel 'splash' feature twists its way around the building. It shields the interior from as much as 30 per cent of the Sun's heat and rises to the 19th floor.

DID YOU KNOW?
By May 2009 the building had reached 100 metres in height; it was completed in December 2011

Did you know?

The tower's lean begins on the 12th floor

© Getty

WORDS **SCOTT DUTFIELD**

WHY WE NEED FLIES

They're some of the strangest and most reviled insects on the planet, but they're also incredibly useful

DID YOU KNOW? Each year, between 1 and 4 billion hoverflies migrate in and out of southern Britain

They're a pest at a picnic, a bin's best friend and an enemy of silence, but flies are also some of the best pollinators on the planet. The first 'true flies', of the order Diptera, flew onto the scene during the middle of the Triassic period around 247 million years ago. Today this order of insects encompasses more than 150,000 different species, including hoverflies, crane flies and mosquitoes, accounting for around 14 per cent of Earth's insect diversity.

The life cycle of true flies generally consists of four stages: egg, larva, pupa and adult. For many flies, the journey to adulthood is short. Female houseflies (*Musca domestica*) can lay up to 500 eggs over a period of three or four days. Under the correct temperature conditions the eggs will hatch in just 20 hours, and larvae will emerge. After developing as a larva for between 4 and 13 days, the maggots pupate – their skin hardens and turns dark brown. While in the pupal stage, their legs and wings form, taking two to six days under optimal conditions, before they emerge as adults. Houseflies have at the very most two months to live, find a mate and reproduce to continue the cycle. The speed of their life cycle means that there can be as many as 20 generations of houseflies zipping around at the same time.

For a long time, flies have been collectively branded as 'bad bugs' – irritating pests that are associated with dirt and disease. And while it's true that many true flies spread diseases, such as *E. coli* and typhoid transmitted by houseflies or infectious malaria administered by mosquitoes, hundreds of

Did you know?

Flies taste using receptors on their legs

A yellow dung fly (*Scathophaga stercoraria*) covered in pollen

© Getty / Alamy

THE BEE MIMIC

At first glance you might mistake these fluffy flies for the world's favourite pollinator, but you won't get any honey from these mimics. Known collectively as bee flies, this is a genus of insects (*Bombylius*) with around 335 member species found around the world. As the name suggests, bee flies bear a close resemblance to bumblebees, and while both are prolific pollinators, the two have some key differences. Unlike bees, bee flies do not have a sting and sport long mouthparts called a proboscis, similar to a butterfly, to lap up plant nectar. As larvae, bee flies start their lives in the entrances to the nests of solitary bees. The bee fly grubs then hunt down bee eggs, larvae and pollen stores to devour before they pupate in the bee's nest and emerge as adult flies.

A dark-edged bee fly (*Bombylius major*) hunting for nectar

A bat fly clinging onto the fur of its host, a Maghrebian bent-winged bat (*Miniopterus maghrebensis*)

A BAT'S RESIDENT VAMPIRE

Meet the bat fly, a parasitic group of flies that either belong to the Streblidae or Nycteribiidae family. As wingless and eyeless insects, bat flies have adapted to hitch a ride on the back of other flying animals, mainly bats. They use tiny claws at the ends of their spider-like legs to latch onto thick bat hair, typically hanging out at their lower back. For sustenance, bat flies feast solely on the blood of their bat hosts. Unlike other fly species, which hedge their bets by laying huge numbers of eggs, bat flies give birth to one developed larva that upon birth, immediately begins to pupate. During this time, a mother bat fly will leave her host, in a rare journey away from the bat, to drop the pupa in the roost of other bats before following the scent of her host back home.

FLYING GIANTS

Typically, flies aren't giants of the insect world. But the Mydas fly family is a group of insects 471 species strong, some of which look more like mouse-sized wasps than flies. One Mydas fly in particular, *Gauromydas heros*, is the biggest of them all. Found in the neotropical forests of South America, these goliaths can grow up to seven centimetres long and boast a wingspan of up to ten centimetres. As adults, male *Gauromydas heros* feed on the larvae of ants and other insects, whereas females don't feed at all. Although they look similar to wasps, they lack their stingers, mimicking their appearance to deter predators.

thousands of species of flies play an important role in our global ecosystem. Where would spiders be without a fly-shaped meal? And what claim to fame would the Venus flytrap have? A Venus 'beetletrap' doesn't have the same ring to it. Like all animals, flies sit within a food chain. From the sharp grasp of a bird's beak to the sticky tongues of frogs, flies find themselves a protein-packed snack for plants and animals around the world. Some salmon farmers use fly maggots as a new protein-rich and sustainable alternative to common fish meal, which is produced from wild-caught anchovies from as far as Peru and Chile.

It might not seem like it, but flies are some of the most efficient pollinators on the planet. While seeking a nectary lunch, many species find themselves inadvertently ferrying pollen from one plant to another. Hoverflies carry pollen as far as 62 miles, assisting in the pollination of 72 per cent of the world's food crops and 70 per cent of the wildflowers that require animal pollination. Farmers in New South Wales, Australia, even employ flies as pollinators to support agriculture as bee populations continue to decline. Researchers at the Australian Department of Primary Industries and Regional Development have been studying the role of flies to support the bee population and pollinate during times when bees can't. Blow flies (*Calliphora*), for example, can work at lower temperatures than bees, allowing farmers to grow crops that require equally cooler temperatures, such as avocado plants, in South West Australia and Tasmania.

As nature's clean-up crew, fly maggots are vigorous eating machines. With hook-like mouths, maggots make an easy job of tearing through food. They even have respiratory openings at the rear, called spiracles, that allow them to breathe while they continually chow down. The collective 'grumble' of maggots feed in such a frenzy and in such large numbers that they can increase the temperature of their meal by up to 53 degrees Celsius, which helps increase the rate of breakdown and digestion. Their voracious appetites mean they make short work of their meals, such as decomposing animals or rotting vegetables, quickly releasing nutrients back into the environment through their waste. These nutrients can then fertilise new plant growth. The next time you look at a fly buzzing around, maybe pause and think about its ecological importance before you swat it with a newspaper.

Did you know?

Flies only have one pair of wings

DID YOU KNOW? Some fly species can detect decomposing protein from almost a mile away

INSIDE A FRUIT FLY

Take a tour of this insect's anatomy

2 BRAIN
The brain of a fruit fly is made up of around 100,000 neurons – a tiny fraction of the 86 billion neurons in your brain.

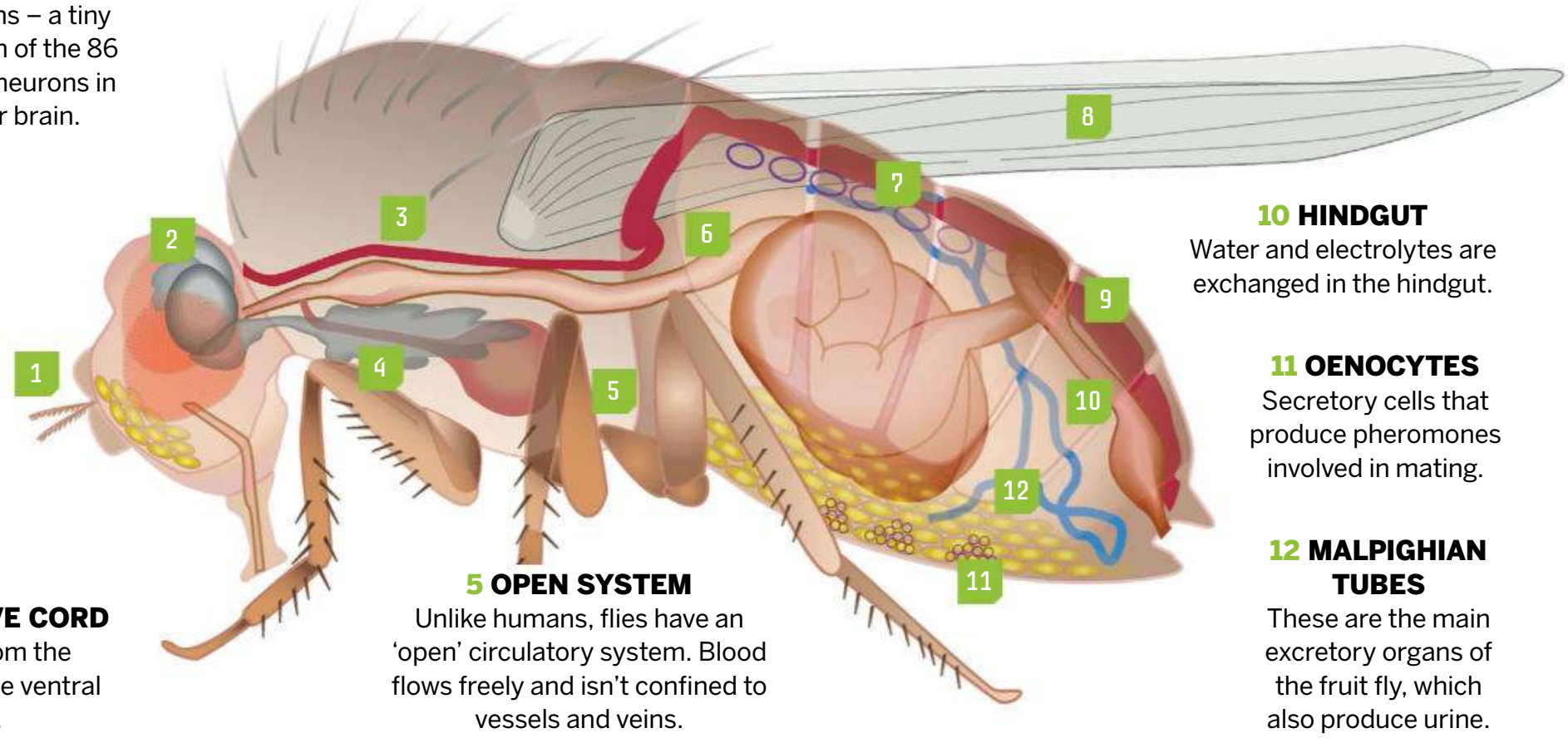
3 AORTA
Blood leaves the aorta and spreads around the fly's body.

6 MIDGUT
This is the home of digestive cells that absorb nutrients and produce hormones.

7 PODOCYTES
These cells eliminate toxins and waste products and maintain pH homeostasis.

8 WINGS
Fruit flies only use 12 tiny muscles to operate their wings.

9 CARDIAC CHAMBER
Blood is pumped around the body through a linear tube of four cardiac chambers.



1 ANTENNAE
Female fruit flies use their antennae to 'hear' the mating songs of their male counterparts.

4 VENTRAL NERVE CORD
Signals to and from the brain are sent via the ventral nerve cord.

5 OPEN SYSTEM
Unlike humans, flies have an 'open' circulatory system. Blood flows freely and isn't confined to vessels and veins.

10 HINDGUT
Water and electrolytes are exchanged in the hindgut.

11 OENOCYTES
Secretory cells that produce pheromones involved in mating.

12 MALPIGHIAN TUBES
These are the main excretory organs of the fruit fly, which also produce urine.

STALK-EYED FLY

Flies come in all different shapes and sizes. But stalk-eyed flies (Diopsidae) are some of the strangest looking flies around. There are more than 100 species of stalk-eyed fly, most of which live in tropical or humid forests. Named after the two protruding eye-bearing stalks stuck to their heads, these flies use their unusual optical anatomy to attract a mate. Studies have shown that female stalk-eyed flies are more attracted to male flies that have bigger and longer eye stalks. As well as finding their future mate, elongated eyes also give males a 135-degree binocular field of view – great for spotting potential partners and possible predators.

A fly falling victim to the web of a hungry spider

Rather than antennae in the middle of their head, stalk-eyed flies have one above each eye

© Getty / Alamy / Science Photo Library

A giant chromosome taken from the saliva of a fruit fly larva

INSECT INSPIRATION

Why flies have had an impact on science

DIAGNOSING DISEASES

You're more closely related to flies than you might think. Fruit flies in particular share 75 per cent of the genes that cause disease in humans. As quick breeders and with a smaller genome than people, fruit flies are a great test subject for scientists to work with to understand diseases that affect humans. Fruit flies have been particularly useful in understanding the aberrant proteins associated with the development of neurodegenerative diseases such as Alzheimer's and Huntington's disease. Similarly, these flies have shown scientists some fundamental mechanisms that lead to the development of cancers and tumours. In the late 1920s, scientists also uncovered the mutative effects of X-rays on an organism's DNA through tests with fruit flies.

PAINLESS NEEDLE

How mosquitoes inspired the design of a pain-free injection

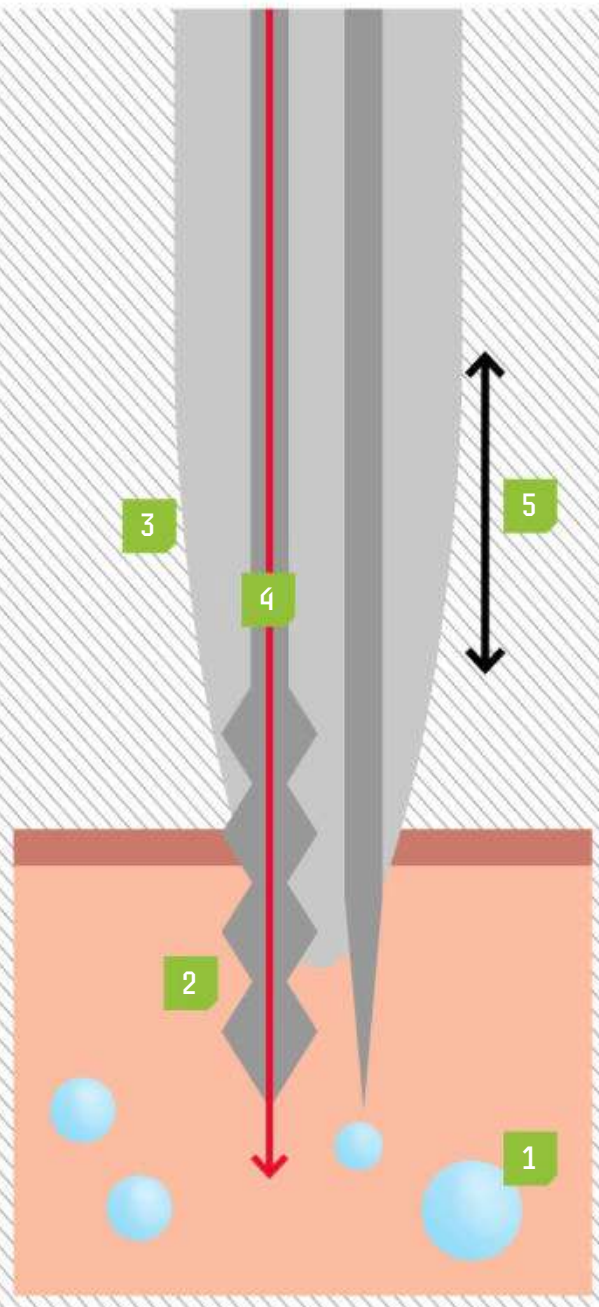
1 NUMBING AGENT
A chemical numbing agent is released in a second microneedle.

2 SERRATED TIP
The secreted end of the microneedle quickly punctures the skin.

3 PROTECTION
The internal microneedles are held in a sturdy over-casing.

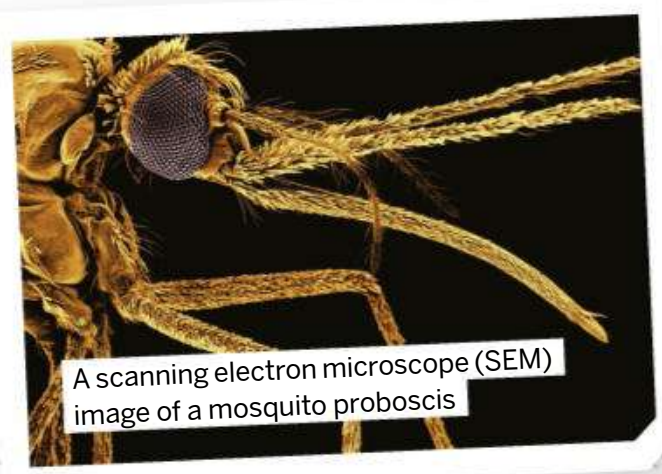
4 INJECTION OR WITHDRAWAL
This microneedle can either inject medicine or draw blood from a patient.

5 VIBRATION
The microneedle vibrates to reduce the force needed to insert it.



MOSQUITO MICRONEEDLES

In 2018, researchers at Ohio State University published the design for a needle-like probe that mimics some of the features found in a mosquito's mouthparts, called a proboscis. Around two millimetres long, the proboscis punctures the skin of the mosquito's victim and siphons out their blood for food. To avoid detection in order to feast in peace, a mosquito's proboscis uses a serrated needle-like structure, vibrates and releases saliva that numbs the site of the puncture. The Ohio researchers focused on all of this to design a microneedle that does the same to draw blood or inject medicine into a patient and reduce the pain of an injection. The insect-inspired design might also help those who suffer from a phobia of needles, or trypanophobia, thanks to its numbing ability.

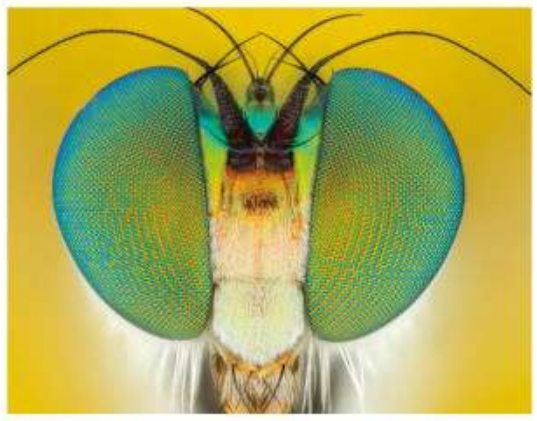


A scanning electron microscope (SEM) image of a mosquito proboscis

DID YOU KNOW? Flies' quick reaction times come from their ability to process around 250 images a second

BIONIC 3D CAMERAS

Unlike humans, flies don't use a single lens to see the world. Instead their eyes are packed with tiny mini lenses that focus light on clusters of photoreceptors, giving them a 360-degree view. This is a quality that bioengineers at the University of California have drawn from to develop a new bionic 3D camera that views things from all angles. The camera array works like a fly's compound eye, but the system also incorporates light detection and ranging technology, which works like bat echolocation, to map out a room, identify an object and view it from multiple angles.



A fly's compound eyes are made up of thousands of tiny lenses

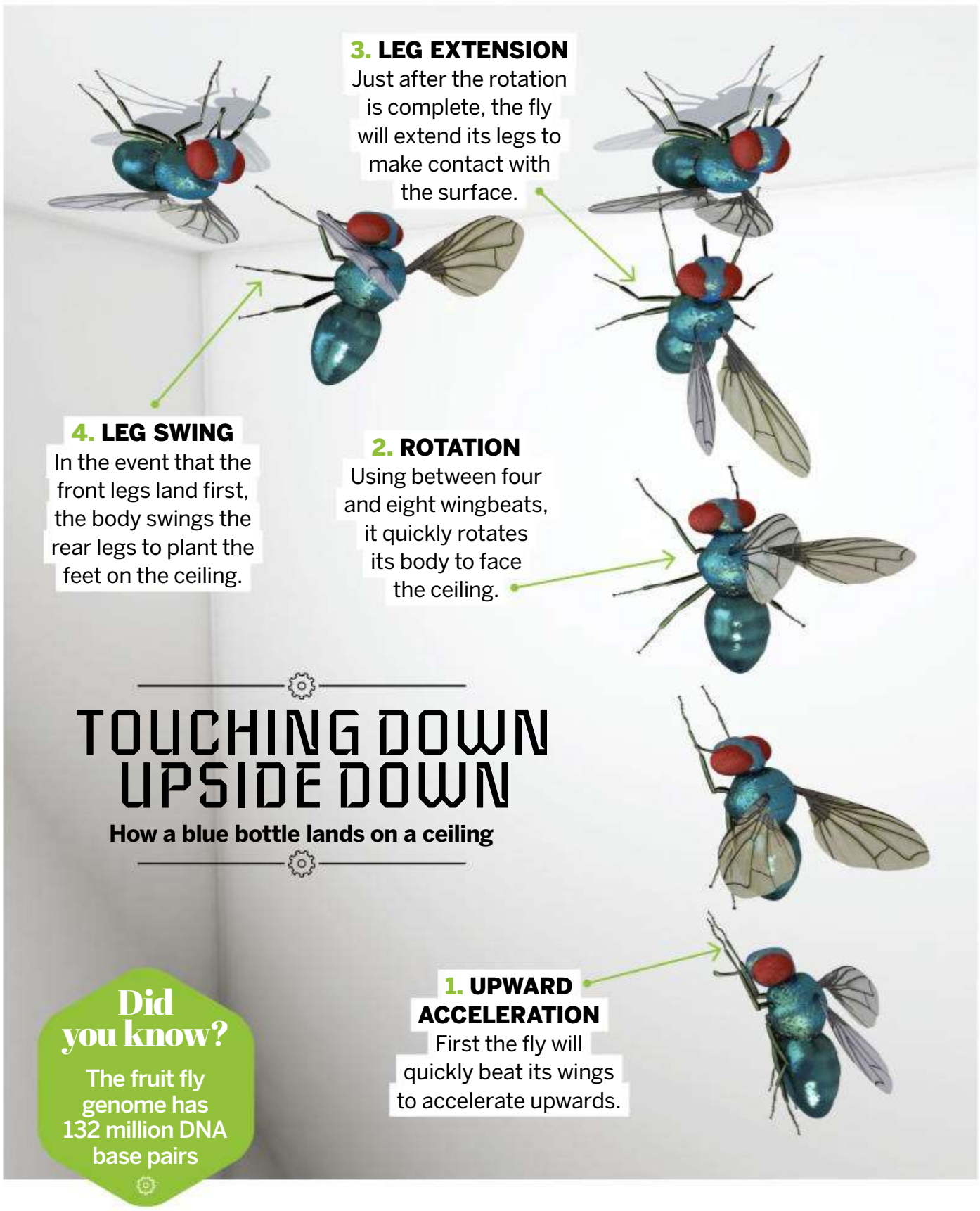
MAGGOT THERAPY

Maggots had long been seen as a bringer of disease, and certainly not as a potential remedy for injured soldiers. That was until military surgeon William Baer discovered their healing abilities in 1917. Thanks to their fondness for necrotic, infected and dying tissue, maggots are used to eat away at unwanted flesh around an open wound, cleaning it in the process. They also release a chemical that breaks down the damaged tissue for easy removal. Maggots also ingest harmful bacteria in the wound, destroying them as they pass through their digestive system.

A patient undergoing maggot therapy to remove damaged tissue from a wound

UPSIDE-DOWN LANDING

Using a high-speed camera, researchers at Penn State University have captured the stages of blue bottle flies (*Calliphora vomitoria*) landing on a ceiling for use in the development of robotic drones. Researchers put the flies into a box and rattled it to get them to fly, then captured how they landed on the roof of the box. Each of the flies that successfully touched down showed the same landing sequence: acceleration, rotation, leg extension and a final leg swing. Any of the flies that missed any of the stages or messed up the timings between them failed to land and bounced off the ceiling. Using machine learning, researchers will try to teach the fly's landing approach to drones in hope that they will one day be able to mimic it.


3. LEG EXTENSION
Just after the rotation is complete, the fly will extend its legs to make contact with the surface.
4. LEG SWING
In the event that the front legs land first, the body swings the rear legs to plant the feet on the ceiling.
2. ROTATION
Using between four and eight wingbeats, it quickly rotates its body to face the ceiling.
TOUCHING DOWN UPSIDE DOWN
How a blue bottle lands on a ceiling
1. UPWARD ACCELERATION
First the fly will quickly beat its wings to accelerate upwards.

Did you know?

The fruit fly genome has 132 million DNA base pairs

© Alamy / Getty / Illustration by Adrian Mann

INSIDE THE WOMB

Take a look inside the mammalian womb and discover how unborn cubs, kittens and calves grow

WORDS **SCOTT DUTFIELD**

Within the animal kingdom, there are three types of mammals: placentals, marsupials and monotremes. Placentals, like humans, carry a foetus within their uterus, also known as the womb. Once a fertilised egg attaches to the lining of the uterus, it develops over several weeks into an early embryo. Along with the development of an embryo, a new temporary organ called the placenta grows.

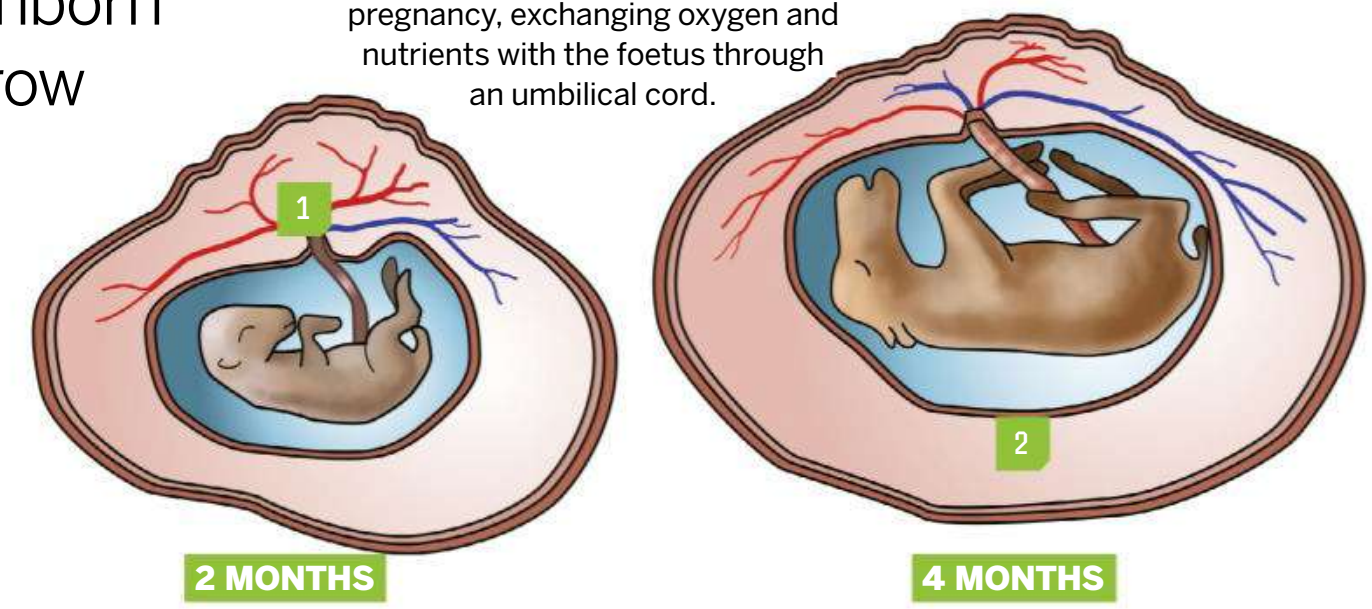
During development, the embryo produces root-like structures called villi, which anchor it in the womb. These villi grow, eventually connecting to the blood vessels of the mother, and the placenta starts to grow. The purpose of the placenta is to deliver nutrients and oxygen to the foetus. The connection between the foetus and the placenta is called the umbilical cord, which leaves a belly button after birth.

To keep the foetus safe during gestation, an encompassing sac of fluid called an amniotic sac also develops to cushion it before it's ready to be born. A placental pregnancy can last anywhere from 11 days to almost two years, depending on the species. But mammals aren't alone in having placental young. Many species of fish, such as sharks, and some reptiles, including skinks, also rely on a placenta to grow their offspring.

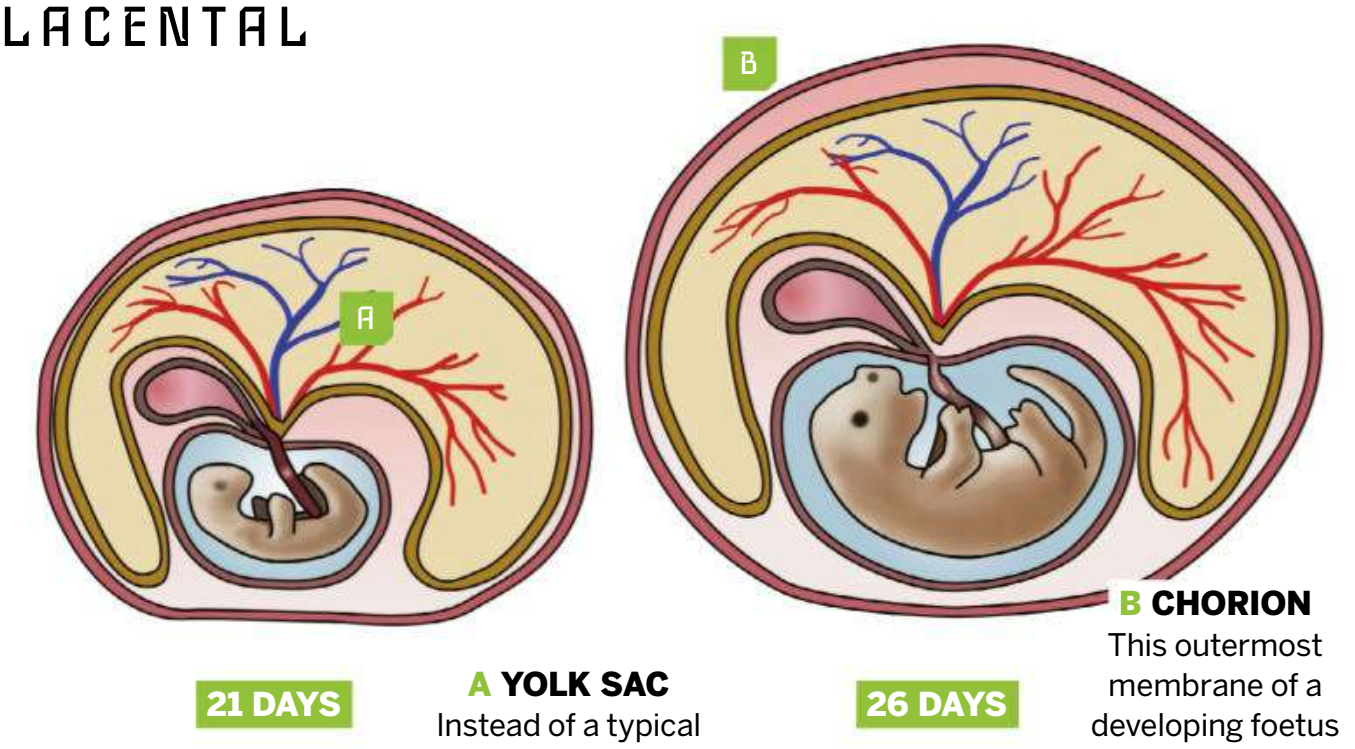
Marsupials have a shorter gestation time than placental mammals, but provide their young with an extended period of lactation. Once a marsupial foetus has spent anywhere from 8 to 42 days in the womb, they make their way into a marsupium, an internal pouch that protects the offspring, and latch onto an available nipple for a lactation period that can last up to 300 days. Monotremes are a class of their own. Only five species are included in this strange group of mammals, including platypus and echidnas. Ditching a womb altogether, these animals pass eggs through an organ called a cloaca.

1 PLACENTA
This organ develops during pregnancy, exchanging oxygen and nutrients with the foetus through an umbilical cord.

2 AMNIOTIC SAC
This thin-walled sac is filled with amniotic fluid to protect the foetus as it grows.



PLACENTAL



A YOLK SAC
Instead of a typical placenta, marsupial foetuses extract their nutrients from a yolk sac.

B CHORION
This outermost membrane of a developing foetus encapsulates the yolk sac and the amniotic fluid.

MARSUPIAL

A stripe-faced dunnart carrying its offspring on its back

SHORTEST PREGNANCY

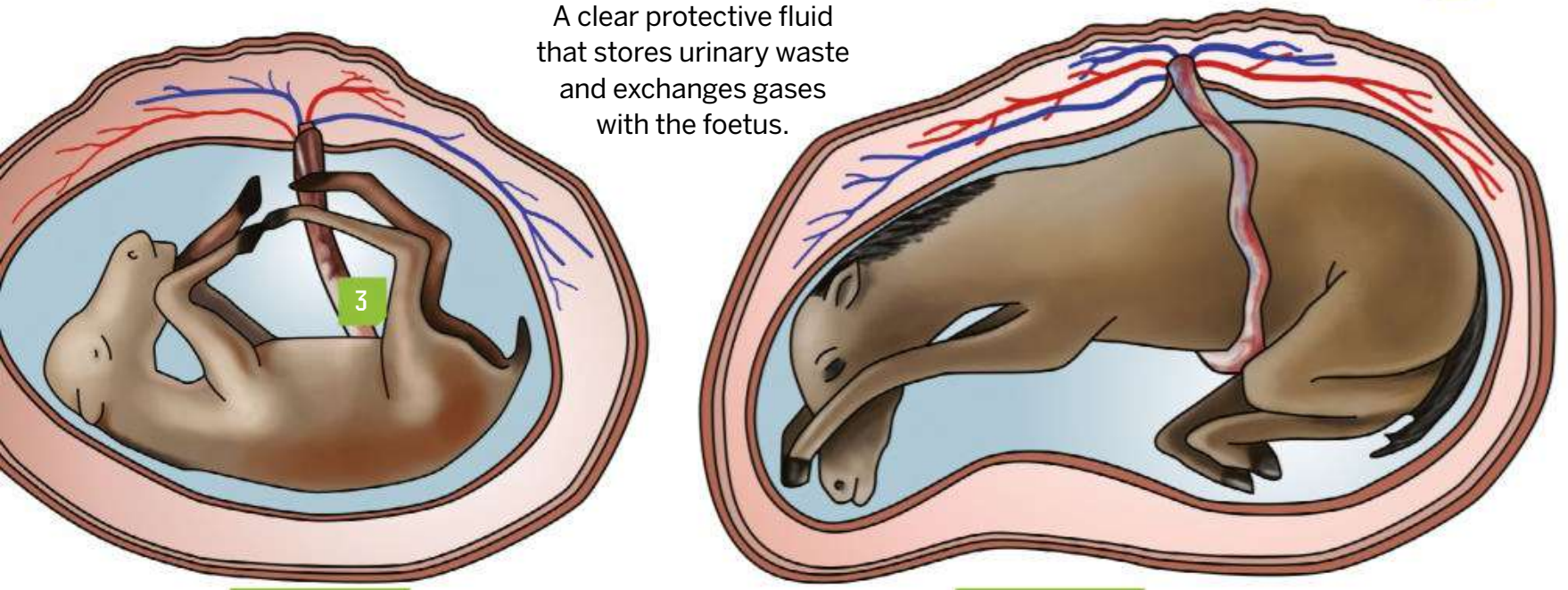
Found in the shrublands of Australia, the stripe-faced dunnart (*Sminthopsis macroura*) is a mouse-sized marsupial that wastes no time when having children. Once a female dunnart reaches adulthood, it finds a mate and produces a litter of around eight young. As a marsupial, foetuses doesn't stay in the womb for long, crawling out after only 11 days of development. The offspring will then suckle on their mother's milk within their protective pouch for a further 40 days before emerging. During low temperatures in winter, these dunnarts enter a hypometabolic state called torpor to conserve energy. This mini-hibernation allows them to survive when food sources are few and far between.

DID YOU KNOW? Madagascan tailless tenrecs can have as many as 32 offspring at a time

PLACENTAL VS MARSUPIAL

How these two different mammals grow their offspring

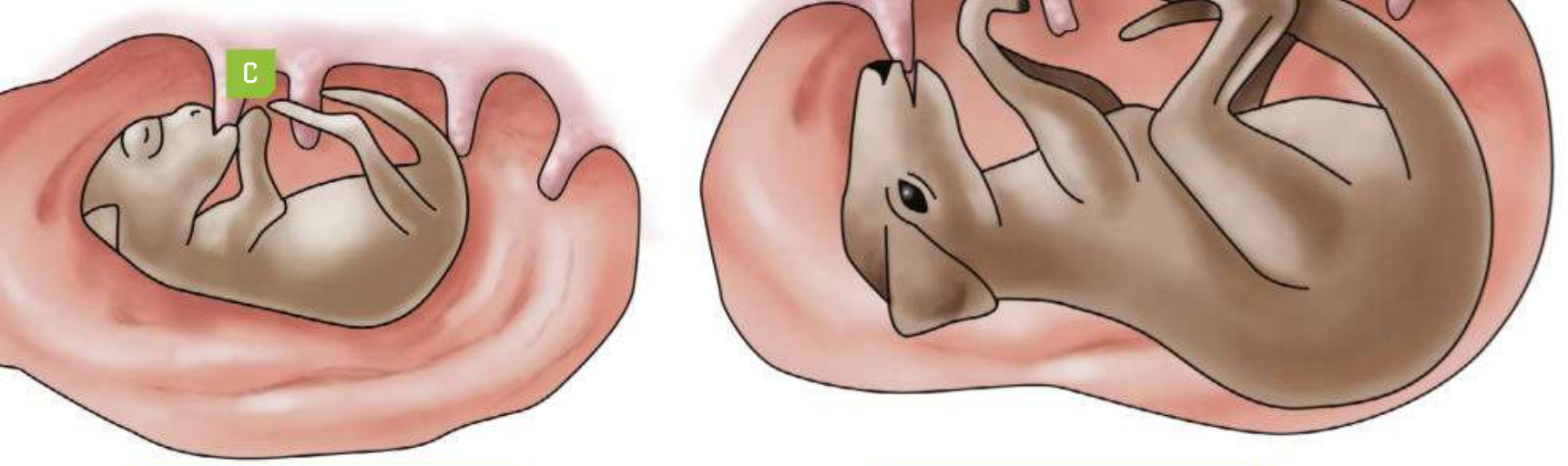
3 ALLANTOIC FLUID
A clear protective fluid that stores urinary waste and exchanges gases with the foetus.



8 MONTHS

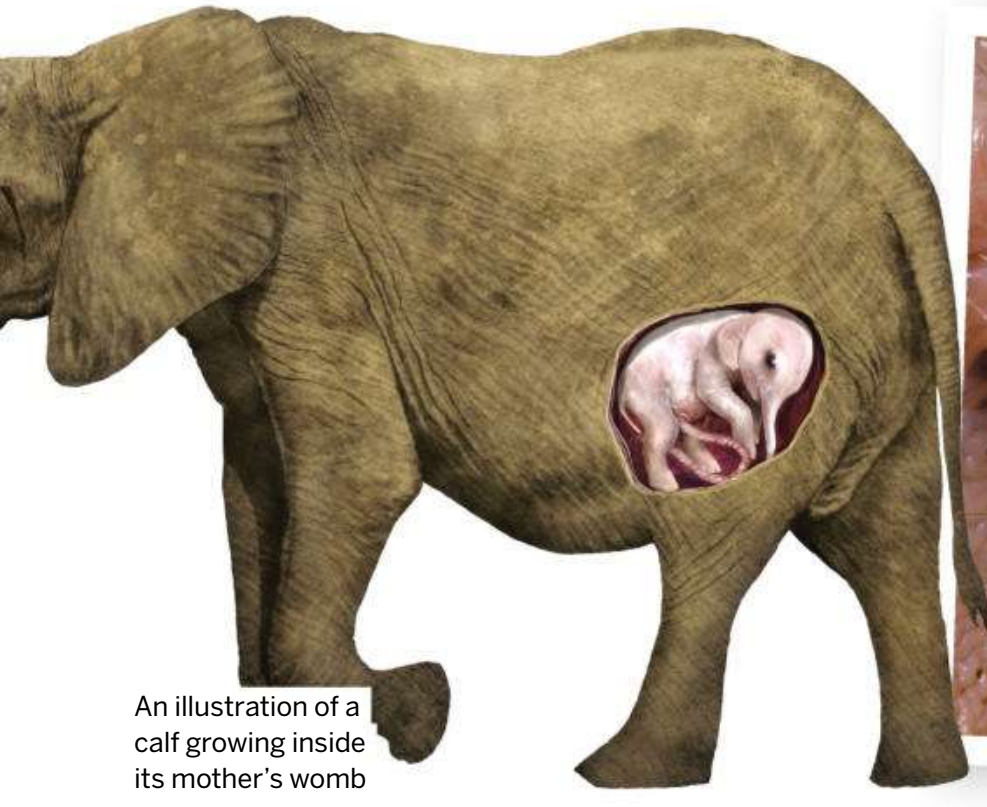
11 MONTHS

C MARSUPIUM
Once a foetus has left the chorion membrane it enters its mother's pouch, known as the marsupium, for several weeks.

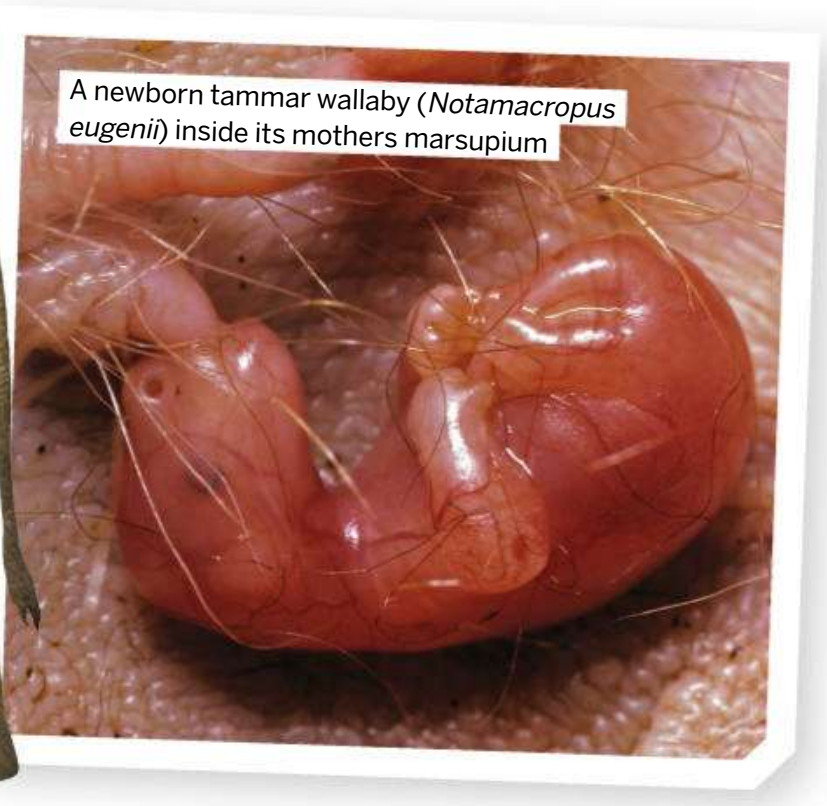


4 WEEKS AFTER BIRTH

12 WEEKS AFTER BIRTH



An illustration of a calf growing inside its mother's womb



A newborn tammar wallaby (*Notamacropus eugenii*) inside its mothers marsupium

Did you know?

Placental mammals diverged around 160 million years ago

GESTATION TIMES

HUMAN
Gestation time:
280 days
Average offspring per pregnancy:
One

ELEPHANT
Gestation time:
669 days
Average offspring per pregnancy:
One

GREY WOLF
Gestation time:
63 days
Average offspring per pregnancy:
Six

BOTTLENOSE DOLPHIN
Gestation time:
365 days
Average offspring per pregnancy:
One

EURASIAN RED SQUIRREL
Gestation time:
39 days
Average offspring per pregnancy:
Seven

ORANGUTAN
Gestation time:
258 days
Average offspring per pregnancy:
One

© Alamy / Getty / Illustration by Adrian Mann

WHAT IS THE SMELL OF RAIN?

After rainfall, this distinctive aroma is released from the soil

WORDS **AILSA HARVEY**

Did you know?

Humans can smell a few molecules of geosmin per trillion air molecules

Despite being an unwelcome form of weather by many, rain is an essential event for sustaining life on Earth. Communities throughout history have always welcomed rainfall as an aid to their growing crops – and scientists think it's for this reason that so many still enjoy the smell that follows the rain. This is called petrichor.

The raindrops themselves aren't responsible for the scent that fills the air after it starts to rain. Rather, the water droplets cause various fragrant compounds to be released from the soil. As raindrops scatter over dry earth, the water traps tiny bubbles of air at the ground's surface. These droplets then splatter, bursting the bubbles from the loose soil and carrying plant oils and other natural chemicals upwards into the air in an aerosol form.

In rainforests, storms can increase the surface ozone layer by 700 per cent

STORMY SCENT

Rain isn't the only weather event that's responsible for natural and distinctive smells. Thunderstorms produce a different scent that's caused by a disturbance in the atmosphere. When lightning strikes through the atmosphere, nitrogen and oxygen molecules split and combine with each other to form nitric oxide and single oxygen atoms. These oxygen atoms then react with oxygen molecules in the air, making ozone (O_3). Ozone is a less stable molecule compared to oxygen's elemental form (O_2). During a storm, air sinks to form downdrafts and pushes ozone lower into the atmosphere where we can smell it. It has a metallic scent, which makes it possible to identify when rain is soon to fall.

PRODUCING PETRICHOR

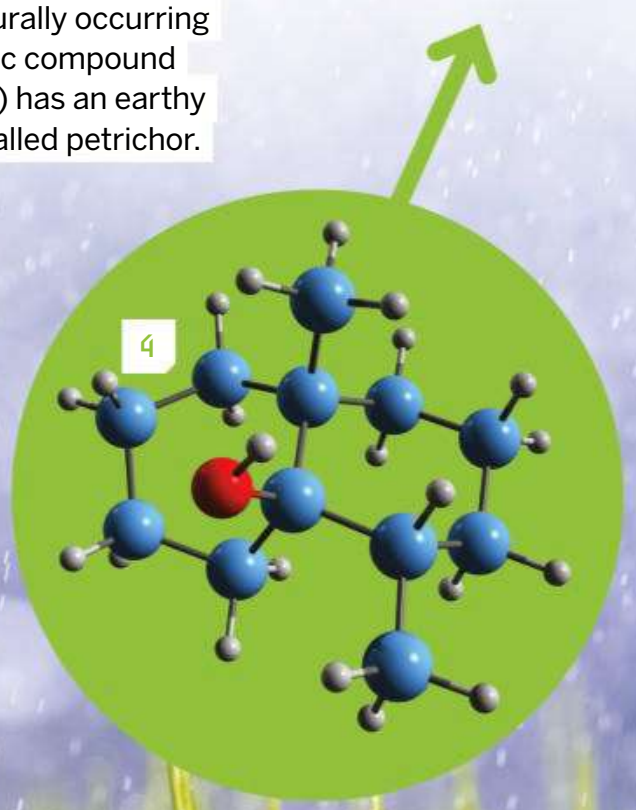
Meet the bacteria partly responsible for rain's earthy scent

1 BACTERIA
A specific type of bacteria called actinomyces release spores from the soil. As they do so, the bacteria also produce a compound called geosmin.

2 OIL ODOUR
When the weather is dry, plants secrete oils. Then, during rainfall, the accumulated oil mixes and bursts into the air to release a stronger earthy scent.

3 RAINFALL
When rain falls onto grass, the damp conditions cause bacteria in the soil to release reproductive cells called spores.

4 GEOSMIN
This naturally occurring organic compound ($C_{12}H_{22}O$) has an earthy smell, called petrichor.



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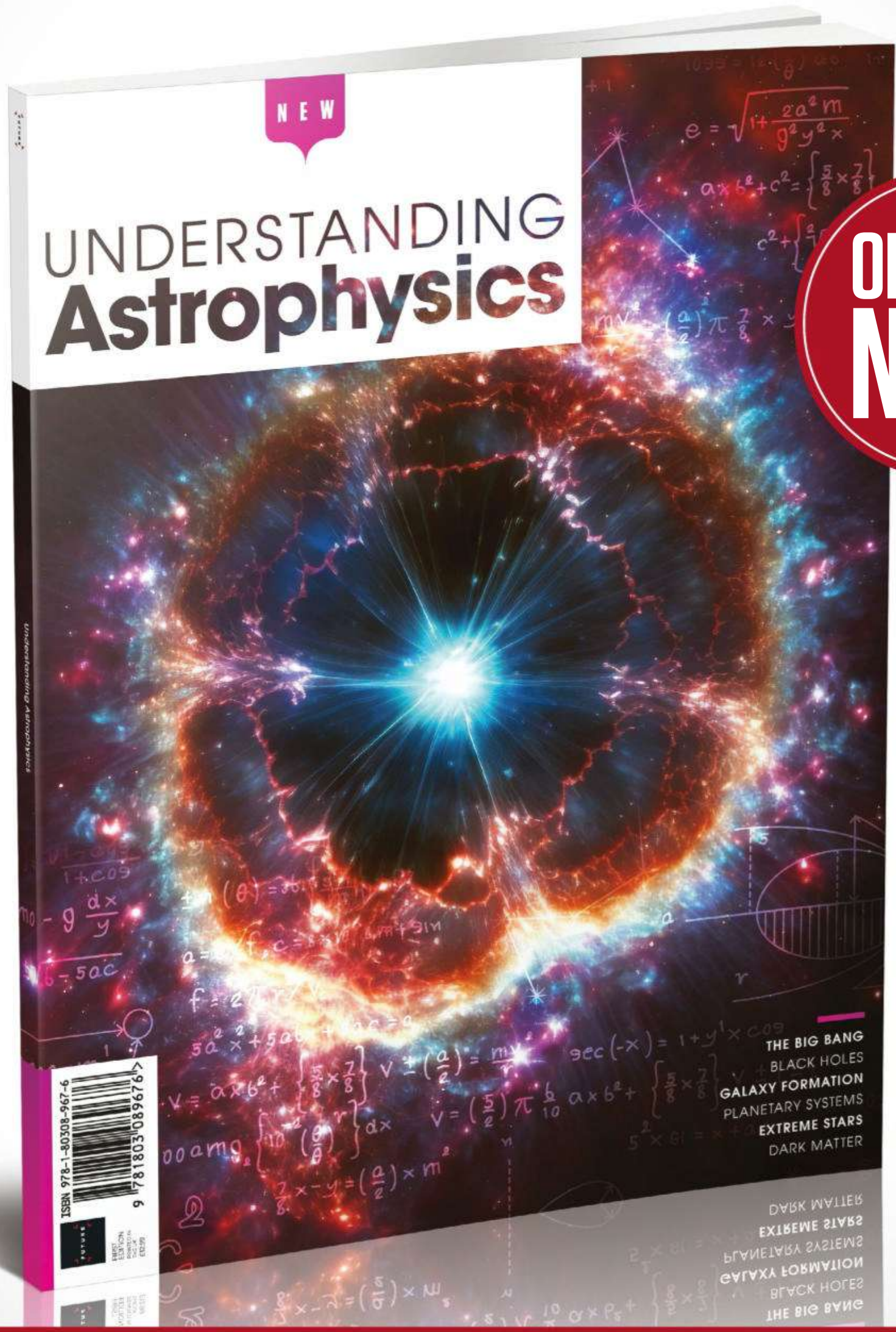
DISCOVER THE WONDERS OF THE UNIVERSE

New from the makers of *All About Space*, this special edition reveals the science that governs our incredible universe and delves into the fascinating theories behind curious cosmic mysteries.



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HOW FORMULA 1 RACING FORMED

Discover the groundbreaking developments that put motor racing in pole position

WORDS **MARK SMITH**

Luigi Villoresi in the Ferrari 125 F1 during the International Daily Express Trophy race at Silverstone in 1949

1 ENGINE
A supercharged 1.5-litre V12 engine produced around 150 horsepower.

2 CHASSIS
It featured a steel tube-framed chassis and a lightweight body, which helped keep the weight down to just 800 kilograms – about half that of a modern family car.

5 ENGINE UPGRADES
The engine was improved as technology evolved, with dual overhead camshafts added in the 1949 season.

4 SUSPENSION
Double-wishbone suspension with a torsion bar and leaf spring helped keep the body low to the ground as it went over bumps.

With blistering speeds, incredible engineering and drivers who went on to become legends, Formula 1 has redefined what's possible when you combine human and machine and set them loose on a track. But the sport we see on our screens today, with its glamour and exotic locales, once looked very different. It can trace its roots back to the very early days of motor racing. In 1946 the first races were held, and a decision was made to launch a championship. It took until 1950 for the rules to be established and the first F1 race was held at Pau in France.

The first races saw the sport very much dominated by the big pre-war manufacturers like Ferrari and Maserati. But the early days were tough going, with a lack of entrants meaning the races weren't as big a spectacle as they are today. It was also much less safe, with 13 drivers being killed during the first decade of Formula 1. Technology advanced the sport, but was hampered when Mercedes Benz pulled out of motor racing following the 1955 disaster at Le Mans – a major crash that saw the death of French driver Pierre Levegh and 83 spectators.

Did you know?
'Formula' refers to the set of rules made for the competition

The 1970s saw huge breakthroughs in vehicle design, with Lotus introducing innovations in aerodynamics that improved cornering speeds. Also in the early 1970s, British business mogul Bernie Ecclestone rearranged the management of Formula 1's commercial rights, turning the sport into a global billion-dollar business. Technology continued to evolve in the 1980s, with semi-automatic gearboxes and traction control. However, this started a discussion about whether Formula 1 was becoming too reliant on technology, rather than the wits and abilities of the drivers. The sport continues to enjoy enormous popularity today, with global viewing figures reported to be a staggering 1.55 billion in 2021.

RACING THROUGH TIME

1906
'Grand Prix' was first used to describe a race in 1901, but the 1906 race outside Le Mans was the first real international Grand Prix.

1933
Starting positions on a grid were decided by qualifying times for the very first time at the Monaco Grand Prix.

1946
Formula 1 was agreed as a recognised formula – marking its official beginning.

1950
Silverstone hosted the British Grand Prix, which marked the launch of the drivers' world championship.

1958
The legendary Sterling Moss won the first race in a rear-engine car.

DID YOU KNOW? F1 cars can accelerate from 0 to 60 miles per hour in 2.6 seconds and decelerate in under four seconds

FORMULA 1 LEGEND

The Ferrari 125 F1 was the iconic company's first Formula 1 car

7 WHEELBASE
The car had an 85-inch wheelbase. This was uprated to 91 inches in 1949.

6 BRAKES
The car had drum brakes on each of its four wheels to help it corner and reduce speed at crucial points of the race.

3 DESIGN
It was one of the first cars to feature a streamlined body that helped reduce drag and increase speed.

8 GEARS
This was a sophisticated gearbox for the time, with five speeds and one for reverse.

9 PERFORMANCE
The vehicle was capable of speeds up to 130 miles per hour, an incredible feat for that era.

5 TYPES OF F1 TECH IN ROAD CARS

1 CARBON FIBRE
A material that was used to reduce weight while maintaining strength and rigidity compared to aluminium components.

2 TURBO
Turbo hybrid power units featuring a turbocharged V6 engine and electric motor were first used in F1 in 2009. Today road cars use it.

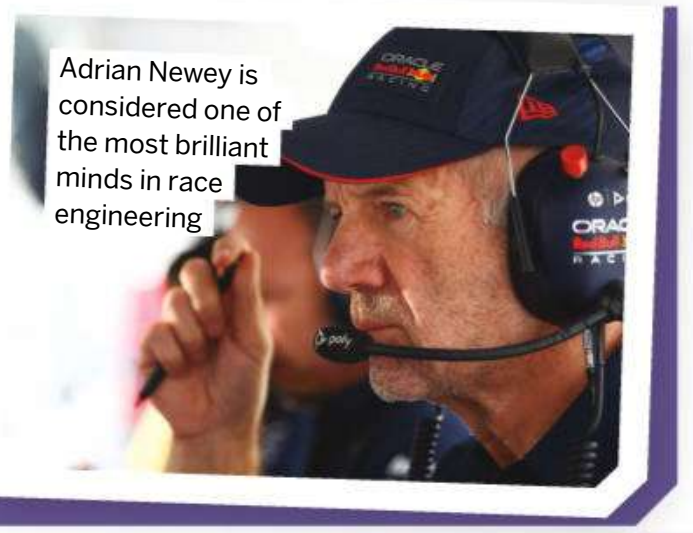
3 REGENERATIVE BRAKING
A kinetic energy recovery system uses braking power to regenerate electric energy in the car's hybrid power units. Road models like the Toyota Prius use it.

4 ACTIVE SUSPENSION
Nigel Mansell's 1992 Williams FW14B featured active suspension, which is now widely used in mainstream vehicles.

5 STEERING WHEEL BUTTONS
Almost every modern vehicle has buttons for certain functions, but the original idea was pioneered on F1 cars.

RED BULL GENIUS

British Formula 1 engineer Adrian Newey is widely considered to be the most important designer in the sport's history. After studying aeronautics at Southampton University and following a stint in the American IndyCar series, he helped design some of the sport's most successful cars. These include those driven by the legendary German driver Michael Schumacher, in which he won five World Championships with Ferrari, and by Sebastian Vettel, who won four with Red Bull.


Adrian Newey is considered one of the most brilliant minds in race engineering

1962
Lotus introduced a revolutionary new design: a car with an aluminium chassis.

1978
Ecclestone became president of the Formula One Constructors' Association.

1982
Lotus unveiled a new active suspension system, signalling the start of electronic driver aids.

1994
Ayrton Senna was killed at the San Marino Grand Prix, triggering a drive to improve safety standards.

2008
The Formula One Teams Association was formed on 29 July.

© Getty / Illustration by Nicholas Forder

HOW ARE CARS RECYCLED?

Step into one of the UK's largest car recycling centres to discover the secrets of a vehicle disassembly line

WORDS **SCOTT DUTFIELD**

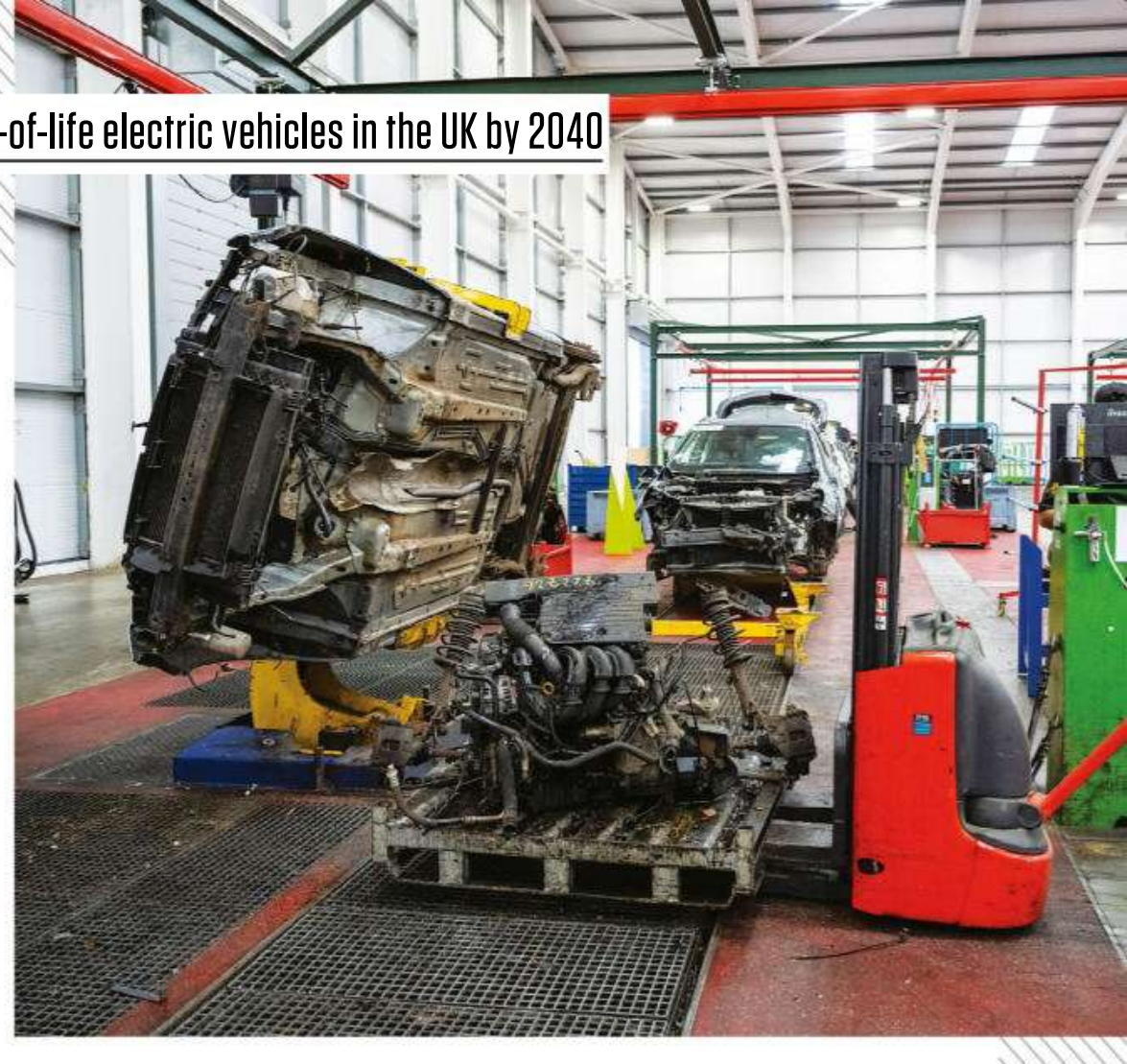
Where do cars go when their engines fail and their exhaust pipes are exhausted? Thousands of cars in the UK find themselves at the pearly gates of Charles Trent recycling centre in Poole, Dorset. Since 1926, Charles Trent has been taking unwanted cars and giving them a new lease of life. The recycling centre has recently added a 12-metre-tall, 8,500-square-metre facility that includes arguably the most advanced salvage and dismantling process in the country. Watching the production line is like seeing the assembly of a car in reverse. Although it's got some of the scrapyard staples, such as the forecourt full of cars awaiting the inevitable crushing by a compactor, the process that leads to them becoming a cube is efficient and leaves no good parts behind.

In the UK, legislation means that the automotive recycling industry must ensure that at least 95 per cent of a car's weight is either recycled, repurposed or resold when it comes to the end of its life. Charles Trent is operating slightly higher at around 96.3 per cent, but its main focus is to capitalise on the reusable parts, as well as what other materials can be recycled.

Upon arrival at the recycling centre, cars are analysed on their quality, and the sum of their saleable parts is evaluated. Generally, if a car has less than 20 resellable parts it continues through to Charles Trent's deproduction line. If a vehicle has more than 20, which are typically higher end motors such as Lamborghinis, then they are moved to a workshop where these parts are stripped by hand. For those left on the deproduction line, within the next hour they will be stripped down to their chassis, which is then compacted and the metal recycled.

Before parts are stripped from the car, its internal fluids must be drained. This process, known as depollution, removes any remaining fuel, oil and coolant from the vehicle and ships it off to a different recycling facility, where it is either cleaned for reuse or recycled into alternative

DID YOU KNOW? It's estimated that there will be 350,000 tonnes of end-of-life electric vehicles in the UK by 2040



products. It's also at this point that batteries and tyres are taken to be recycled. Typical lead-acid car batteries are a hot commodity and are quickly stripped and sold from used cars. When they are not viable for reuse, their components are broken apart. The sulphuric acid inside them is drained, and in some cases repurposed as an industrial chemical. Then the plastic casing is smashed and melted to make new batteries. Similarly, the rechargeable lithium-ion batteries in the body of an electric vehicle are recycled for use in alternative energy storage.

Another environmental hurdle to tackle while recycling a car is the tyres. Since 2002 there has been a ban on tyres from cars and agricultural vehicles being dumped in landfill sites in the UK. This is largely because of their inherent combustibility and the toxic leachate they can unleash into the environment. While some are repurposed in playgrounds, as go-kart track barriers and sold as 'part-worn' tyres for a discounted price, many tyres are too bald and broken to be reused. Millions of old tyres are either sent to the shredder to be broken down into the raw materials to make more tyres, or they are incinerated.

Once a car has been emptied and is ready to be picked apart, it makes its way over to the deproduction line. Over the next 24 hours, the car will pass through several stages of disassembly. From car doors to radio wires, there's not much left behind once it's gone through this part of the process. At each stage of disassembly, engineers are presented with a sort of shopping list to gather the parts suitable for reselling. Each part is given an ID tag that will stay with them through the rest of the process. Some parts, such as brake discs and scrap metal, are not saleable items and find themselves passed onto steel foundries to be melted down and repurposed.

> "Before parts are stripped from the car, its internal fluids must be drained"

After everything that's destined to be resold has been removed from the car, Charles Trent's staff perform a diligent quality check on each part, cleaning and preparing it for resale. The rest of the car is transported to the on-site crusher to be squashed down into compact cubes. Facilities such as this crush around 100 cars per day. The car cubes are then shredded into small pieces of metal and plastic, which are either again melted down and repurposed into new materials or sent to landfill.

Charles Trent has become one of the 81 vendors that are part of eBay's Certified Recycled scheme, which is certified by the Vehicle Recyclers Association (VRA). The company has adapted its process to include small photo booths and upload stations in order to image and digitally stock its eBay store. To house its eBay supply chain, Charles Trent has created a metropolis of shelving units 11 metres tall, all marginally spaced apart. Thousands of car panels, headlights, engines and more can be found on its well-stocked shelves, ready for online purchase. When a car part is purchased, a forklift driver needs only to use the part's ID tag to locate and unload it off the shelf before packing it ready for shipment.

The entire dismantling process is impeccably streamlined, which not only benefits production efficiency, but the wider environment, too. Sellers purchasing 'green' car parts through eBay's certified centres, such as Charles Trent, saved 16,000 tonnes of carbon dioxide from entering the atmosphere and 3 million kilograms of waste from landfill in 2022 alone. The facility's crusher is also run solely on renewable electrical power that's generated by connected solar panels.

Below left: From door panels to engines, all car parts for sale are stored on palettes in a series of enormous shelves

Above left: What's left of a car is crushed into a neat little cube

Above: There's not much left after workers have stripped a car down

Did you know?

There are around 33 million cars in the UK

© Charles Trent

ON THE DISASSEMBLY LINE

How Charles Trent has streamlined scrapping cars to make the most out of each vehicle

1 ASSESSMENT
Cars are initially assessed for quality and a shopping list of parts is determined.

2 DEPOLLUTION
After assessment, all leftover fuel, oil and coolants are extracted and either shipped away for further treatment or repurposed.

3 WAITING ROOM
Vehicles are held on metal racking before they're placed on the disassembly line.

4 PANEL REMOVAL
The first pieces to be taken off the car are its panels, doors and bonnets.

5 ELECTRICAL REMOVAL
Centre consoles and lights are next to be removed.

6 ENGINE REMOVAL
With the help of a mechanical arm, the car's engine, gearbox and catalytic converter are cut away.

7 WIRE STRIPPING
Internal dashboard wiring, heating controls and radio system electronics are stripped.

DID YOU KNOW? 1.6 billion tyres are made each year; 100 million are made of recycled materials

These cars along the dismantling line are about to have their panels removed

Each car part is given its own ID tag to catalogue the products heading for the online store

11 PHOTOSHOOT
Once a part is ready for sale, it's photographed and uploaded to eBay.

12 STORAGE
Parts are packaged and put on shelving units that have a capacity for 71,000 parts.

8 MECHANICAL DISMANTLING
At this part of the process, gearboxes are separated from the engine and the engine is inspected and cleaned.

9 PANEL PREP
Car panels are inspected and cleaned, as well as being repaired if necessary.

10 QUALITY CHECKS
Quality checks are made throughout. A final check is made before parts are set aside for resale.

Did you know?
The Ford Focus is the UK's most scrapped car

Engines and gearboxes being loaded into the engine washer

ENGINE CLEANER

Every engine that's removed from a car needs a good scrub before being resold, ready to be used in a new vehicle. To grapple against the grease and polish the pipes, car engines are placed into an enormous dishwasher-like machine. Once all the pipes and inlets have been plugged up, the engine is loaded into the machine and placed on a wash cycle, where it will be powerwashed with high temperature water that will evaporate once the engine has been cleaned.

These automated forklifts can ascend to around 11 metres high

A TIGHT SQUEEZE

With less than a couple of metres between the centre's towering shelving units, Charles Trent has employed equally tall forklift trucks that autonomously guide themselves through the narrow aisles. To minimise the risk of a domino effect of toppling shelves, a radio frequency identification (RFID) system replaces manual steering by human drivers. This works using a thin RFID strip that lines the floor around the shelves. When a forklift is manually driven to connect with the strip, its steering wheel is disabled, leaving the driver to concentrate on operating the lift to collect palettes, moving backwards and forwards along the RFID strip running along the centre of the aisle.

© Charles trent / Illustration by XXXXXX

INSIDE A ROAD-PAVING MACHINE

How these specialised vehicles pave the way for smooth and long-lasting roads

WORDS **AILSA HARVEY**

Over 25 million tonnes of asphalt is made in the UK each year, which has resulted in a network of over 250,000 miles of paved roads in the country. A properly paved road can last around 20 years, but this depends on the strength and material of the road, as well as environmental factors. The most common materials used are asphalt and concrete. Asphalt consists of rock, tar or gravel, and concrete is made of water, sand and cement.

Paving vehicles are vital pieces of equipment for road workers to ensure efficiency and consistency during long days of construction. Some of these machines are towed by a lorry, but most pavers today have wheels and are self-propelled, allowing an operator to navigate directly in the vehicle's cockpit. Pavers help prolong the usability of roads by optimising the compaction of asphalt. If the asphalt is too loose, water can drain into the gaps, leading to erosion and collapse. By contrast, asphalt that's over-compacted makes the road more prone to cracking.

PAVER PARTS

Explore the mechanics required for flawless road surfaces

5 PAVER OPERATION
After adjusting the new road's width and thickness, the operator drives the vehicle from this cabin.

2 THICKNESS CONTROL SCREW
Moving this component up and down controls the screed angle and the thickness of the asphalt layer released.

6 TRACTOR
This contains the engine, controls and hydraulic machinery for overall vehicle movement and distribution of asphalt.

3 TOW ARM
The screed is attached to the tractor here. The higher the point at which the arm attaches to the paver, called the tow point, the thicker the asphalt layer.

4 SCREED
The screed is the section of the vehicle that controls the release of asphalt. It contains a flat plate which smooths over the fresh asphalt to compress and flatten it.

DID YOU KNOW? Around 80 per cent of asphalt removed from roads is reused for new road-laying projects

Did you know?

Asphalt has been used for paving since 1815

ROAD BREAKDOWN

What are the different layers of a road?

A TOP THREE LAYERS
The asphalt surface, intermediate and base layers are laid onto the aggregate base layer in three coatings by the paver. By adding separate thinner layers, the road can be compacted much more easily.

B FOURTH LAYER
An aggregate base is laid for strength. It's made up of crushed rock and is often recycled asphalt. The material is spread over the road before being rolled flat.

C BOTTOM LAYER
The road is built directly onto the subsoil. This lower layer is naturally found under topsoil and has a light colour. The topsoil is removed before the road is laid, but this subsoil layer shouldn't be compacted as it requires gaps for water drainage.

MAKING ASPHALT

When the asphalt is loaded into the paving machine, it's in the latter stages of being transformed into a road surface. Before it reaches the paver, asphalt is distilled, emulsified and pulverised. Asphalt is produced during the distillation process of petroleum, which involves 'cracking' oil into everything from light jet fuel to heavy tars. The heavy deposits are collected and ground down into small, powdered pieces and mixed with oil to make a thick, smooth mixture. After the desired consistency is achieved at an asphalt plant, trucks transport the mixture to road-paving sites. Here the asphalt is poured into the paver, ready to be laid.

Asphalt ingredients are mixed together in large containers at the asphalt mixing plant, ready to be loaded onto the backs of trucks

1 HOPPER
This section holds and mixes the asphalt material before the vehicle dispenses it.

7 TRACKS
Tracked pavers have higher traction and stability than wheeled pavers, enabling roads to be laid on steep slopes and other challenging terrain.

© Alamy / Getty

Galileo's GREATEST DISCOVERIES

Peer into the mind of this trailblazing astronomer and discover his pioneering observations

WORDS **SCOTT DUTFIELD**

DID YOU KNOW? Two of Galileo's fingers are on display at the Galileo Museum in Florence, Italy

Using a brass telescope of his own design, Galileo spent hours spying on worlds beyond our own. What he discovered changed the way we viewed the Solar System. Born in Pisa, Italy, in 1564, Galileo Galilei spent his youth as a keen musician and medical student at the University of Pisa. However, like so many other great minds, Galileo felt the pull of mathematics and found himself immersed in the worlds of mechanics and astronomy. Before his rise to academic stardom, the world largely viewed the universe through the eyes of Greek philosophers such as Aristotle. Based on the existence of celestial spheres and an Earth-centric view of the universe, the science of astronomy in the early 16th century was very much in its infancy. At least until Galileo began a scientific revolution using a new invention.

Arguably his most important contribution to science was the creation of his refracting telescope. Having discovered a new instrument called the spyglass in 1609, Galileo began experimenting with how he might use it to magnify his view of the world and beyond. Although Galileo didn't technically invent the telescope, which was first patented by Dutch eyeglass maker Hans Lippershey, his modifications to the original design gave him the ability to gaze at the stars with unrivalled precision. Wasting no time, Galileo pointed his telescope towards the stars for the first time in 1610. The year that followed was filled with lunar discoveries, solar revelations and planetary observations that changed the way we view the celestial residents of space. From Moon craters to Saturn's 'ears', Galileo saw objects in space up close using his refractor telescope, which he developed to have a magnification of up to 30 times.

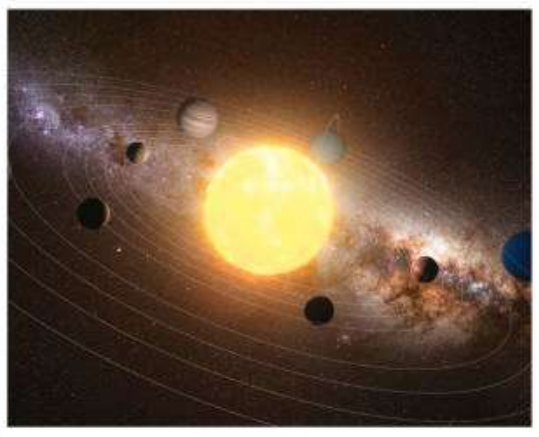
Although Galileo's astronomical observations eventually enlightened the world of science, the Catholic Church wasn't so keen to see the universe through his eyes. Despite being a man of faith himself, Galileo faced persistent opposition from members of the church who had deemed his work heresy. Following a ban on his books by the Catholic Church and a short stint in prison, Galileo remained under house arrest for the rest of his life. However, his many contributions to science live on, as does the knowledge that inspired future scientists to create spacecraft that have journeyed to places Galileo first spotted through the lens of his telescope.

Did you know?

Galileo went blind at 72 years old

THE CENTRE OF THE UNIVERSE

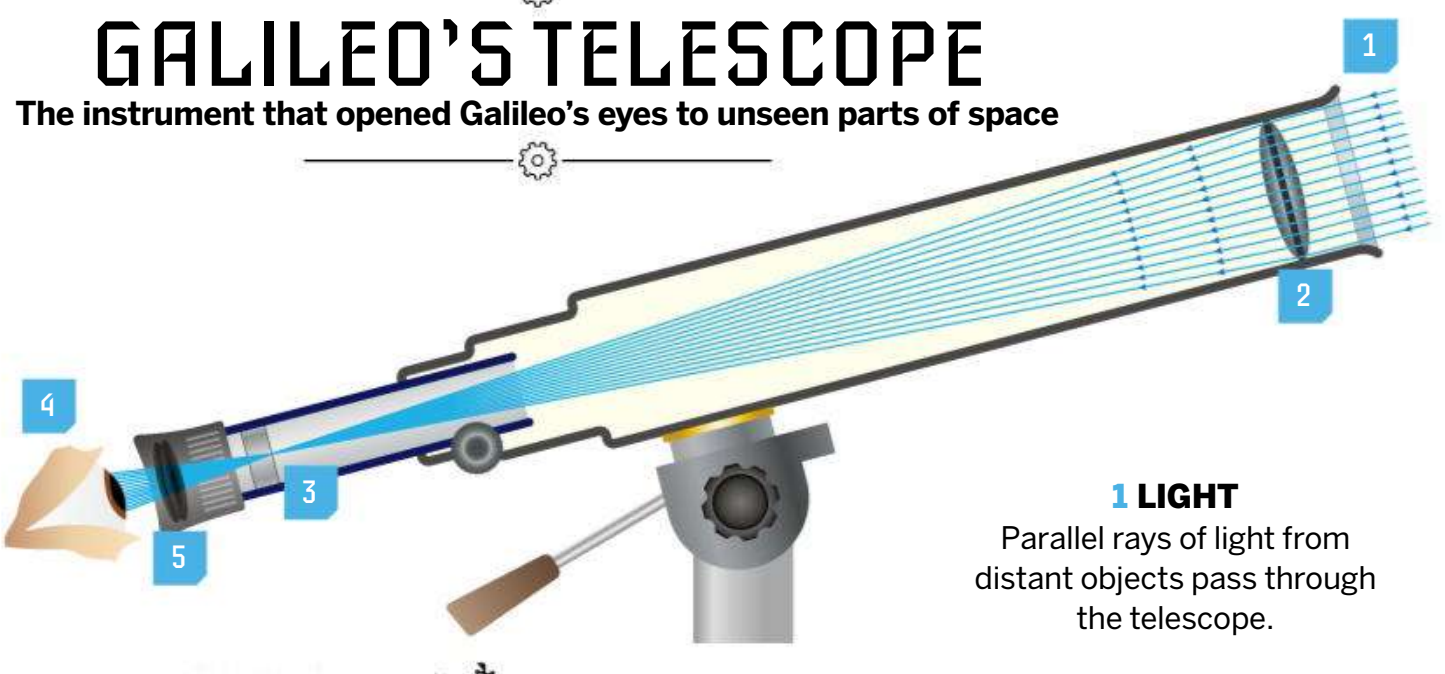
For almost 1,500 years the world's greatest minds believed that Earth sat at the centre of the universe. This model, which was known as the geocentric or Ptolemaic system, was named after the Alexandrian astronomer Claudius Ptolemy. It wasn't until the early 16th century that a Renaissance astronomer and polymath named Nicolaus Copernicus proposed a new system that would replace Earth with the Sun as the centre of the universe. This new heliocentric model was slow to gain acceptance among the scientific community and faced furious opposition from religious leaders, who deemed his work heresy. That was before Galileo and his telescope came along. Through his observations of the movement of Venus and Jupiter's moons, Galileo's discoveries supported and cemented Copernicus' heliocentric model as fact.



An illustration of the heliocentric model of the Solar System

GALILEO'S TELESCOPE

The instrument that opened Galileo's eyes to unseen parts of space



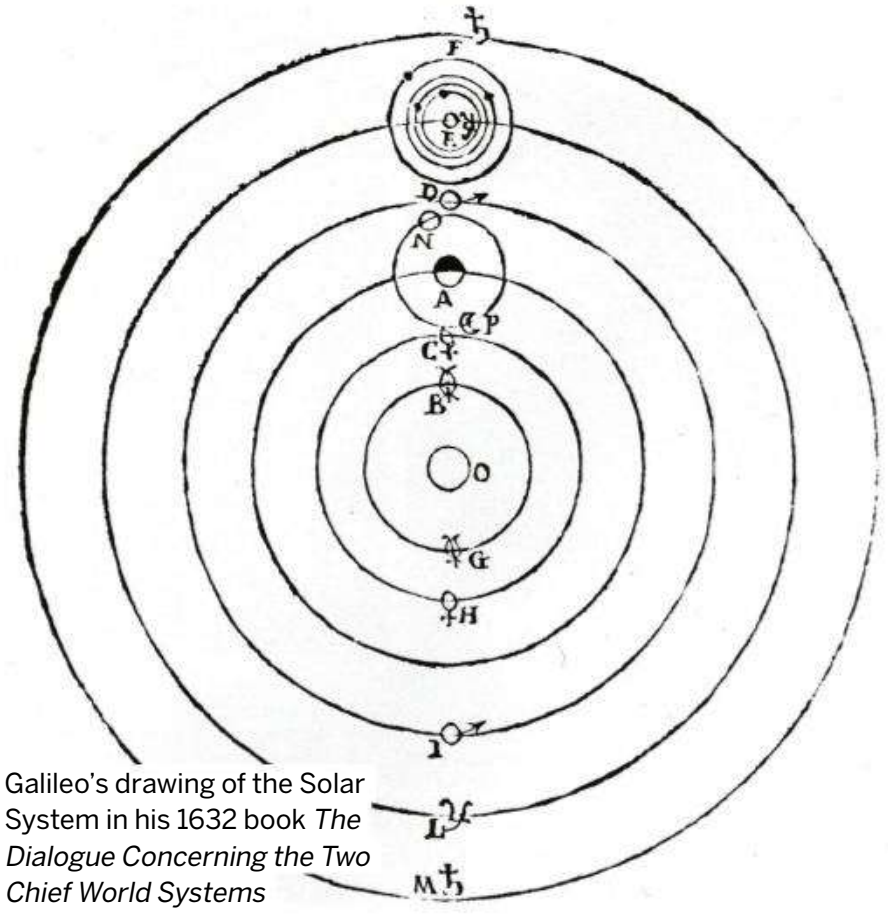
1 LIGHT
Parallel rays of light from distant objects pass through the telescope.

2 CONVEX LENS
When light rays hit the glass convex lens, they are bent, or refracted.

3 FOCAL POINT
The once-parallel rays converge after passing through the convex lens and meet at a focal point.

4 UPSIDE-DOWN IMAGE
Past the focal point, the rays of light cross, meaning the final image is seen upside down.

5 EYEPIECE
The eyepiece is placed in front of the focal point, straightening the rays out and projecting them as an image of the object onto the eye's retina.



Galileo's drawing of the Solar System in his 1632 book *The Dialogue Concerning the Two Chief World Systems*

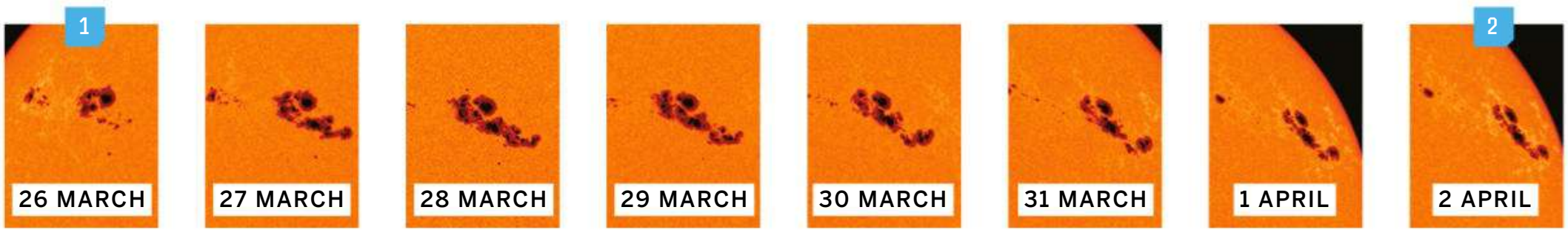
© Alamy / Getty / Shutterstock

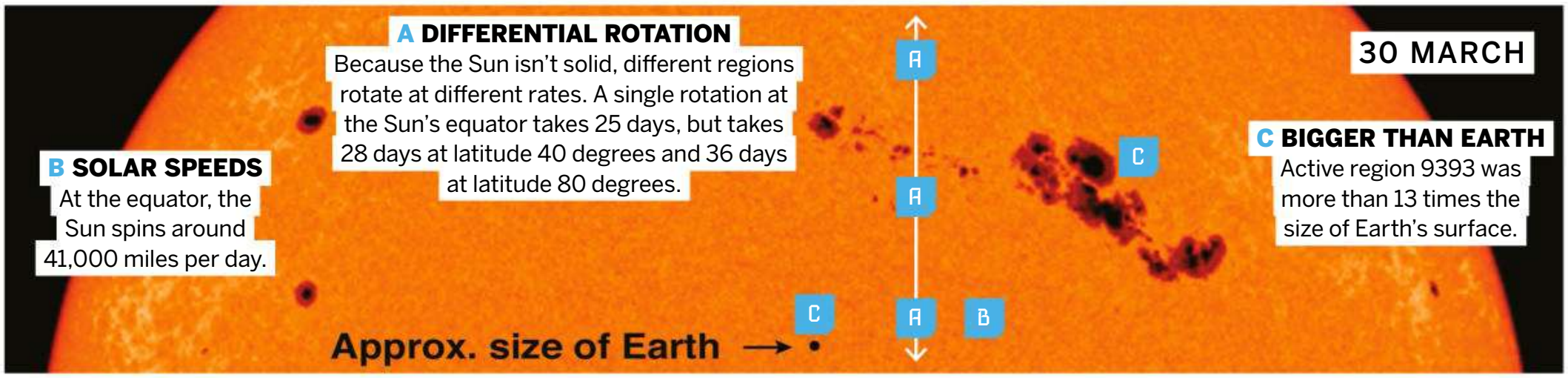
TRACKING SUNSPOTS

How a 2001 sunspot moved with the spinning Sun

1 SNAPPED FROM SPACE
This series of images was taken by the Solar and Heliospheric Observatory in March 2001. It was called active region 9393 and spanned 150,000 miles across the Sun's surface.

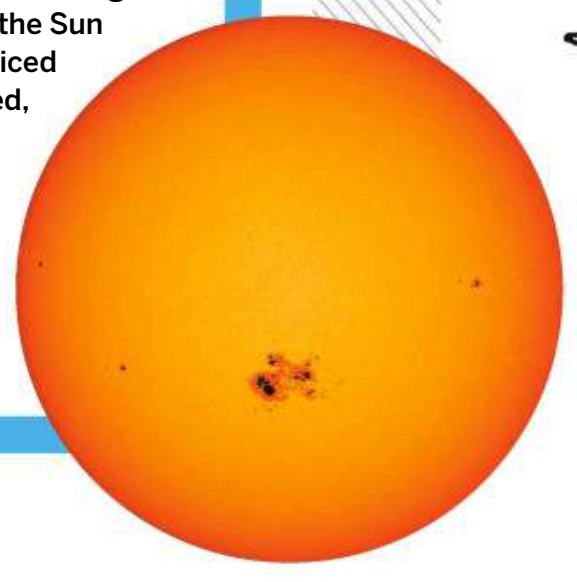
2 SHOWING MOVEMENT
Over the course of a week the sunspot appeared to have travelled thousands of miles, from one side of the Sun to the other.




30 MARCH
A DIFFERENTIAL ROTATION
Because the Sun isn't solid, different regions rotate at different rates. A single rotation at the Sun's equator takes 25 days, but takes 28 days at latitude 40 degrees and 36 days at latitude 80 degrees.
B SOLAR SPEEDS
At the equator, the Sun spins around 41,000 miles per day.
C BIGGER THAN EARTH
Active region 9393 was more than 13 times the size of Earth's surface.
A
A
A
B
C
C
Approx. size of Earth

SPOTTING SUNSPOTS

Taking inspiration from the work of German astronomer Christoph Scheiner, Galileo also pointed his telescope at the giant ball of light in the sky in search of sunspots. We now understand that sunspots are the sites of solar flares and coronal mass ejections, forming dark spots on the Sun's surface that burn at thousands of degrees. They form as a result of the Sun's twisting magnetic fields, which produce sudden bursts of solar activity. Galileo was none the wiser about the source of these solar anomalies, but he did use them to discover that the Sun was moving. Scheiner concluded sunspots weren't fixed to the surface of the Sun, but were instead small planets closely orbiting it. Galileo contested this, instead suggesting that the markings confirmed that the Sun is rotating on an axis. While observing the Sun and its spots, Galileo noticed that the dark spots moved, vanished and returned over time.

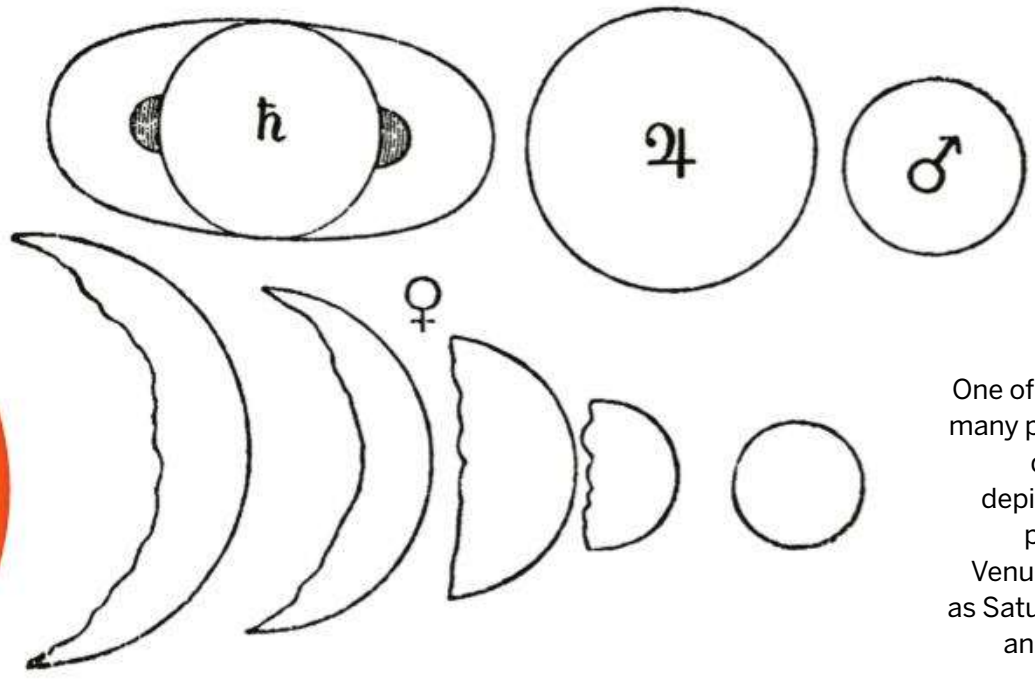


A sunspot, almost 80,000 miles wide, captured by NASA's Solar Dynamics Observatory in 2014

THE PHASES OF VENUS

Three years after his groundbreaking observations, Galileo published his *Letter on Sunspots* in 1613. In this, Galileo offered a more disruptive finding about Earth's neighbour Venus. Before Galileo's telescope, the sunlight reflected from the surface of Venus led people to believe it was nothing more than another star. To the naked eye, Venus appears to rise ahead of the Sun at dawn and behind it at dusk. In the Ptolemaic model of the Solar System, this was attributed to Venus moving in a circle as well as orbiting Earth. In the morning, Venus would be at the front-most point in its mini orbit, then at the farthest most point during the evening, making it look like it was behind the Sun.

But when Galileo took a look at Venus, he discovered that it didn't appear as it should according to the Ptolemaic model. For the Ptolemaic model to be correct, we wouldn't be able to see the fully sunlit side of Venus, only the light at the edges at the extremes of its mini orbit. However, this isn't what Galileo saw. Over several months, Galileo tracked the so-called star and discovered that, like the Moon, Venus entered a series of phases. The only way that Galileo could witness the stages of change from a full, brightly lit Venus to an unlit 'new' planet is if Venus orbited the Sun rather than Earth. Galileo's discovery of Venus' phases meant that Copernicus' model of a heliocentric system was justified.



One of Galileo's many planetary drawings depicting the phases of Venus, as well as Saturn, Mars and Jupiter

DID YOU KNOW? It's estimated that Saturn will completely lose its rings in 300 million years

PICKING OUT STARS

Before Galileo gazed upon the Milky Way, the visible part of our galaxy was widely believed to be nothing more than a whitish cloud, then known as a nebula, passing across the sky. It was common consensus among astronomers during the early 17th century that it formed from interactions between heavenly bodies, referred to as celestial and terrestrial spheres. However, when pointing his lens at the nebula, Galileo realised that its bright light came from a collection of stars. In *Sidereus Nuncius*, Galileo described what he saw as a "congeries of innumerable stars grouped together in clusters too small and distant to be resolved into individual stars by the naked eye." Little did Galileo know that this cluster of stars was part of a galaxy 100,000 light years wide and home to billions of stars.

A view of some of the 100 billion stars that make up the Milky Way

DISCOVERING JUPITER'S MOONS

In 1610, Galileo pointed his telescope towards Jupiter. While observing the planetary giant he noticed three sources of light that he immediately attributed to far-off stars. However, over several nights the movement of the unknown stars remained in proximity to Jupiter. After a few more nights of keen observations, he noticed a fourth star also bound to the planet. Upon discovering the fourth star, Galileo concluded that, like Earth's Moon, Jupiter also had moons that orbited around it.

Did you know?

Jupiter has between 80 and 95 moons

Galileo published his discovery of Jupiter's moons in a book titled *Sidereus Nuncius* (*Starry Messenger*), along with details of the telescope used to spot them.

Today we know the Galilean moons as Io, Europa, Ganymede and Callisto, names given to them by Johannes Kepler almost 200 years after Galileo spotted them. However, Galileo originally wanted to call them the Cosmica Sidera, before naming them Cosmio, Francesco, Carlo and Lorenzo after the brothers of Cosimo II de' Medici of Tuscany, who Galileo had tutored in 1605.

An illustration of one of Jupiter's moons, Ganymede, orbiting the gas giant

THE FOUR GALILEAN MOONS

EUROPA

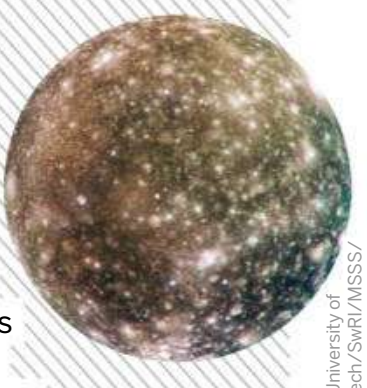
At around one-quarter the diameter of Earth, scientists believe that Europa has a 15-mile thick ice shell that's floating on a saltwater ocean up to 100 miles deep. It's also been suggested that Europa has all the ingredients needed to support some form of life beyond Earth.

GANYMEDE

It's not only Jupiter's largest moon – Ganymede is the biggest natural satellite in the entire Solar System. Around 2.4 times smaller than Earth, this moon has a radius of 1,635 miles. Ganymede is also the only known moon to have its own magnetic field.

IO

This is the most volcanically active of Jupiter's moons. Sending lava dozens of miles into its sulphur dioxide-filled atmosphere, Io is home to hundreds of volcanoes that continue to smooth its surface by filling in impact craters. It remains unknown what its lava is made of, but the best scientific guess suggests it's molten sulphur or silicate rock.



CALLISTO

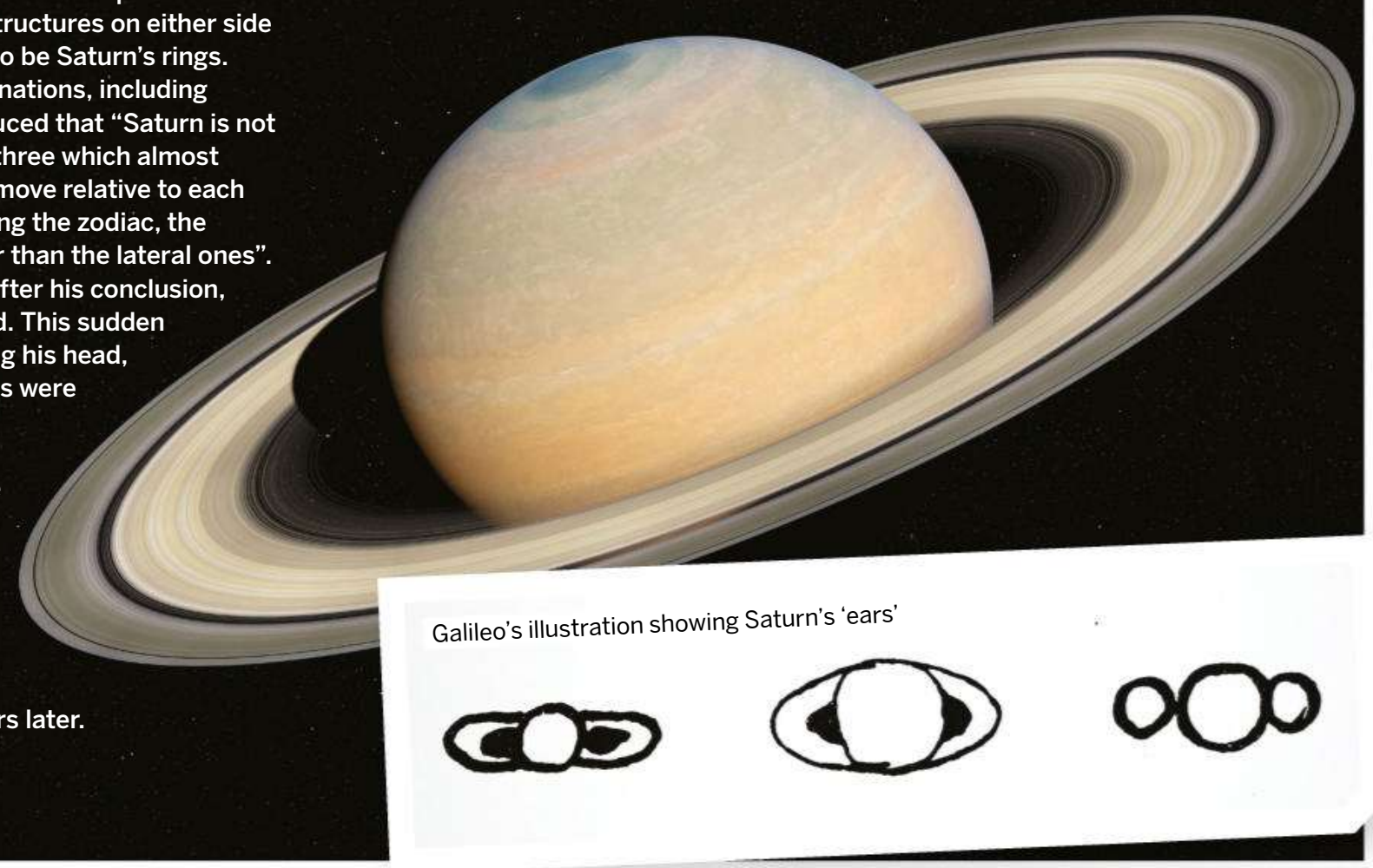
Once believed to be a pretty uninteresting moon, the Galileo spacecraft revealed that Callisto may be hiding a subterranean ocean around 155 miles below the surface. The ocean may be interacting with interior rock and metal, giving it the potential to support life.

© Getty / NASA/JPL/University of Arizona/DLR/JPL-Caltech/SwRI/MSSS/ Kevin M. Gill/SDO/SOHO (ESA & NASA)

SATURN'S 'EARS'

As great as Galileo's observations were, not all of them were completely spot on. Training his telescope towards Saturn, Galileo spotted two large structures on either side of the planet – what we now know to be Saturn's rings. Having contemplated several explanations, including jug-handle-like projections, he deduced that "Saturn is not a single star, but is a composite of three which almost touch each other, never change or move relative to each other and are arranged in a row along the zodiac, the middle one being three times larger than the lateral ones".

Much to his surprise, two years after his conclusion, the two structures had disappeared. This sudden absence likely left Galileo scratching his head, but we know now that Saturn's rings were edge-on and appeared invisible to observers on Earth. Twice during Saturn's 29.5-year orbit around the Sun, its thin rings, which are around 0.6 miles thick, align edge-on with Earth and disappear when viewed through a telescope. Galileo needn't have worried too much, as Saturn's ears reappeared in the lens of his telescope two years later.



Unknown to Galileo, Saturn has a ring system that extends 175,000 miles from the planet

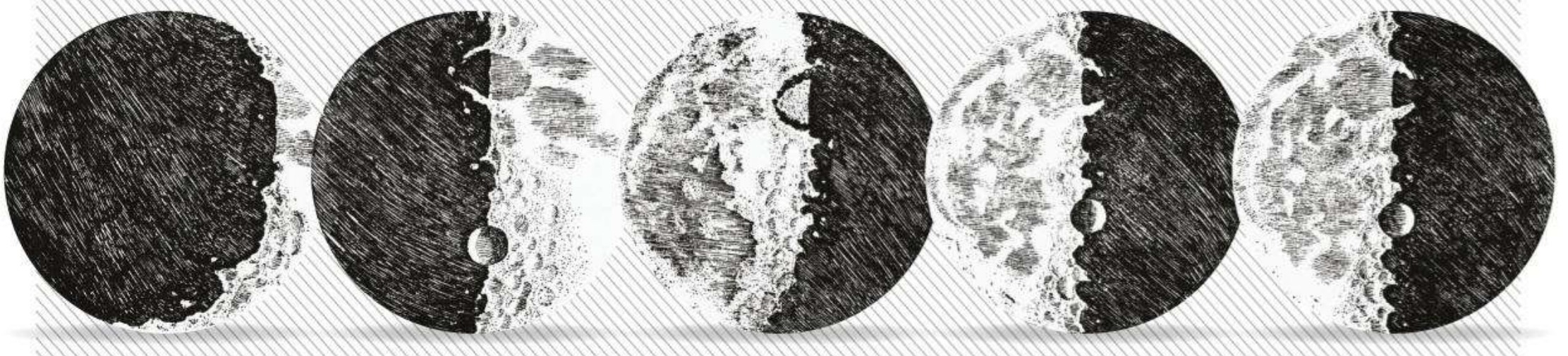
Galileo's illustration showing Saturn's 'ears'

PUTTING CRATERS ON THE MOON

The Moon was once thought to be unlike Earth's mountainous terrain, having a completely smooth surface. During the Renaissance, the Moon, along with other celestial bodies, existed in the heavenly realm, and therefore didn't have the same mountainous imperfections seen on Earth. However, once again one of Galileo's observations defied the connection between the celestial bodies and religious doctrine. In discovering some of the many craters and valleys on its surface, Galileo knocked the Moon off its heavenly pedestal and showed that it's not so different to Earth. As a competent artist, Galileo depicted the textured surface of the Moon, along with its phases, in a series of illustrations published in *Sidereus Nuncius*. As well as finding mountainous features, Galileo was able to accurately calculate their heights using a mathematical equation that included the length of the shadow they cast, Pythagoras' theorem and the known 2,000-mile diameter of the Moon.

The surface of the Moon isn't as smooth as astronomers in the early 1600s thought

Galileo's sketches of the Moon, published in *Sidereus Nuncius* in 1610



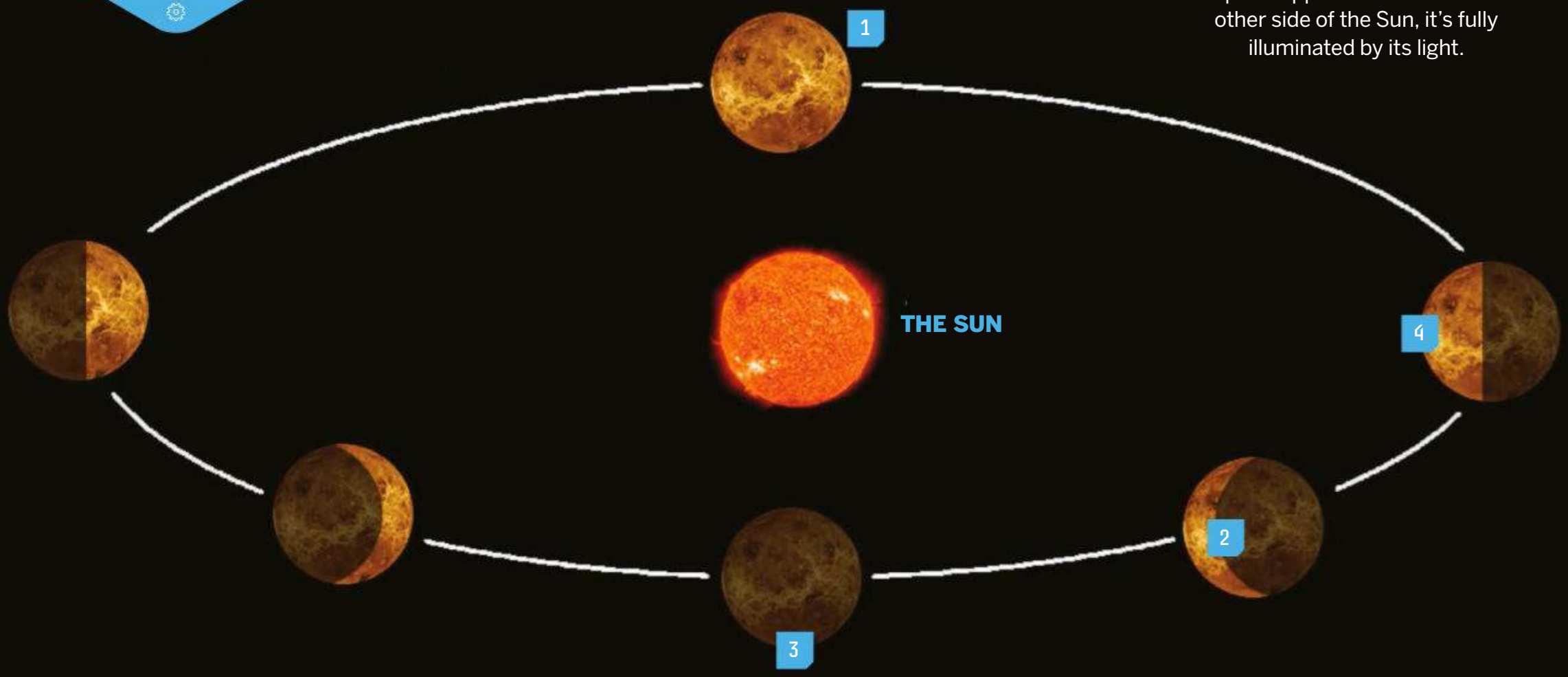
DID YOU KNOW? In 1992 Pope John Paul II officially repealed the condemnation of Galileo's work

Did you know?

A day on Venus is longer than a year

VENUS' ORBIT

How the planet travels around the Sun



1 SUPER CONJUNCTION
Once every 225 days, Venus completes an orbit of the Sun. When it reaches the point opposite Earth on the other side of the Sun, it's fully illuminated by its light.

2 CRESCENT VENUS
Venus is brightest in Earth's sky during the crescent phase both before and after the inferior conjunction, or 'new' Venus.

3 INFERIOR CONJUNCTION
When Venus is closest to Earth – around 38 million miles away – its Sun-facing side is obscured from view.

4 GREATEST ELONGATION
When around 50 per cent of Venus' surface is illuminated, it has reached its great elongation – the maximum angle between Venus and the Sun, which is 47 degrees.

5 SPEEDY VENUS
Orbiting faster than Earth, Venus zips around the Sun at around 78,337 miles per hour, whereas Earth trails behind at around 67,000 miles per hour.

An 1857 painting of Galileo being investigated for his heliocentric beliefs

British intellectual John Milton met with Galileo in 1638

© Alamy / Getty

LIVING ON THE MOON

What would a lunar colony be like?

WORDS **AILSA HARVEY**

A total of 12 people have stepped on Earth's natural satellite, but could we call it home? Astronauts will be making fresh footprints in its dusty regolith in 2025 after a 50-year absence. Yet even now scientists have ambitions of achieving a long-term human presence on the Moon. Since the last Apollo landing, NASA and other space agencies have been experimenting with new technologies, spacecraft and architectural plans for lunar living. Currently, the main reason behind building a permanent base camp on the Moon is to get closer to other planets, such as Mars, and provide a platform for deeper observation into the universe.

Did you know?

The Moon moves 3.78 centimetres away from Earth each year

The Apollo missions equipped researchers with a sample of knowledge from just six crewed Moon landings. One of the most significant revelations came after analysing Moon and Earth rocks and discovering that the Moon likely formed from Earth debris. By spending more time there, astronauts on future Artemis missions will explore untouched areas of the Moon and conduct research into how different cells – including those of their own bodies – react to space exposure. They will retrieve data on what makes a successful landing in the Orion spacecraft and lunar lander, as well as the journey between Earth and the Moon. Sending humans to a largely unexplored alien environment is fraught with danger, but through assessing both known and new risks, astronauts will be able to properly assess the possibility of colonising the Moon as they widen our understanding of the Solar System.

NASA's pressurised rover concept increases the range of exploration on the Moon

BUILDING A MOON BASE

This is an example of what a future lunar settlement could look like

2 HABITAT DOMES
Long-term settlements need protection from radiation, extreme temperatures, meteorite impacts and debris. This could involve building homes inside craters and covering them up.

2

Lunar soil doesn't contain any organic matter

VITAL RESOURCES

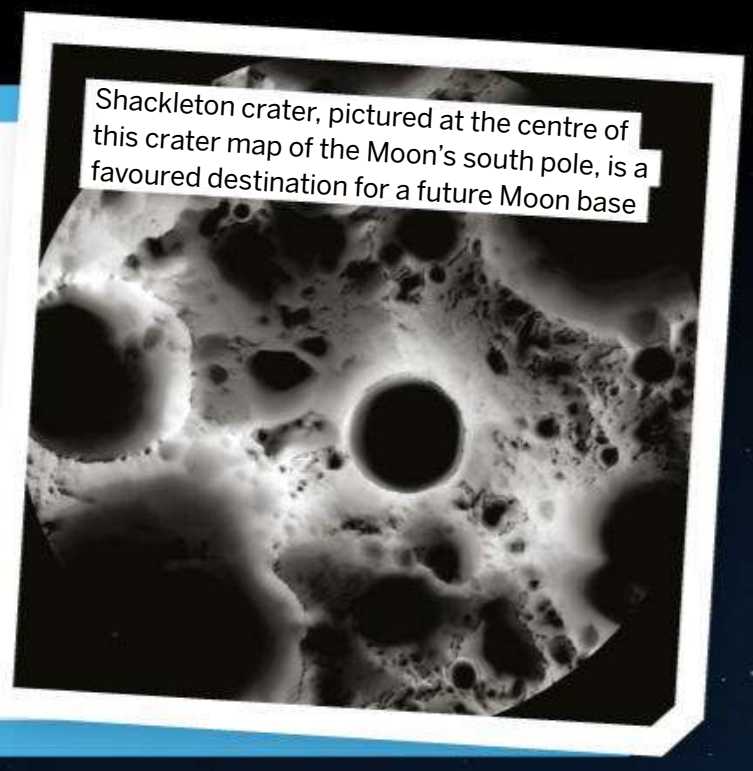
The lunar environment is in stark contrast to much of planet Earth, as the Moon cannot sustain life naturally. However, using innovative engineering technologies, settlers could transform the scarce resources into the basic items that they require to live there. Lunar soil is made up of 42 per cent oxygen, which can be extracted as breathable air with heat and electricity. Meanwhile, lunar rovers would work daily to search for, drill into and collect lunar ice. As for lunar agriculture, plants can't receive the same levels of water, carbon, nitrogen and phosphorus from the lunar soil that they need to thrive on Earth. However, NASA scientists have successfully managed to grow cress plants in the soil collected during the Apollo missions.

DID YOU KNOW? Due to the lower gravity, a skyscraper built on the Moon could reach several miles high

BASE CAMP

Before launching for the Moon, a target destination needs to be established. NASA is focusing on a shady part of the Moon's south pole for its Artemis missions, as this is believed to be the best place to sustain life long-term. A colony here would benefit from the icy deposits that remain in this colder area. The permanent shadow this area experiences is because the Sun is never positioned more than 1.5 degrees above or below the horizon. Humans living on the Moon could process the ice here to obtain drinking water, oxygen and hydrogen fuel. Sunlight falls on the protruding surfaces of the south pole, and this can be used to harness solar power.

Rather than building a single base on the Moon, it's much more likely that multiple bases will be constructed at one time. This is largely due to the fact that launches from Earth are much more limited if there's only one destination: if the specific launch window is missed, astronauts need to wait around one month until their launchpad and Moon camp align again.



Shackleton crater, pictured at the centre of this crater map of the Moon's south pole, is a favoured destination for a future Moon base

3 SOLAR ARRAYS
Craters at the Moon's south pole have near-constant sunlight exposure and no cloud coverage. Solar panels alone could create enough electricity to power a Moon base.

In November 2022, Artemis' Space Launch System rocket and Orion spacecraft carried out a test launch for the next Moon mission

5 AIRLOCK
Habitat domes need an airlock entrance. This sealed chamber switches between the internal and external pressures to prevent the pressure changing inside the domes.

4 GREENHOUSES
Plants grown on the Moon need to be contained in greenhouses to control the atmosphere and to collect waste gases and water.

1 PRESSURISED VEHICLES
These lunar rovers are pressurised so that astronauts can ride inside without wearing bulky spacesuits.

6 WORKING ROVERS
Autonomous or remotely controlled rovers assist the Moon's inhabitants by being the first to assess an area's safety. These machines can also dig into soil.

© NASA/GSFC/Arizona State University / Alamy / NASA; Joel Kowsky

WHY JUPITER'S GREAT RED SPOT IS VANISHING

Jupiter's complex weather system is sapping its famous red spot at an alarming rate. And scientists predict the feature could vanish within our lifetimes

WORDS COLIN STUART

One of the Solar System's most iconic features may be on the way out. Astronomers using the Hubble Space Telescope recently measured Jupiter's Great Red Spot and found its diameter to be the lowest ever recorded. If it continues shrinking at its present rate, it could be gone within two decades.

The Great Red Spot is an anti-cyclonic (anti-clockwise) storm in Jupiter's southern hemisphere and is large enough to contain three Earths. With winds raging at 270 miles per hour, it's one of the fiercest storms in the Solar System. It's possible that it was first observed as far back as the 1630s, not long after the invention of the telescope. However, accurate measurements of its size began in the late 1800s. At that point astronomers noted its diameter as 25,500 miles. By the time NASA's Voyager space probes sidled up to Jupiter in 1979, the spot had shrunk by almost a half. And early Hubble images taken in 1995 revealed it had withered to just 13,020 miles.

More recently, in 2014, astronomer Dr Amy Simon of NASA's Goddard Space Flight Center in Maryland was alerted to the fact the disappearing act seemed to be picking up pace. "It was amateur astronomers who flagged it up," she says. The oval-shaped storm seemed to be getting more circular, so Simon applied for time on Hubble to investigate. "It was just 10,250 miles across," she says. Simon is studying past observations to see if she can uncover the cause of the demise. "We've spotted small eddies feeding into the storm," she says. "We're looking into whether that might be the cause."

It's a difficult task. "We're watching weather on another planet – it's hard enough to predict the weather here on Earth," Simon explains. Yet those efforts will help us understand what factors sap or add momentum to this enormous anti-cyclone and help us predict when one of the Solar System's most illustrious and well-known features may be gone for good.

Did you know?

The Great Red Spot is up to 300 miles deep

> "We're watching weather on another planet – it's hard enough to predict the weather here on Earth"

DID YOU KNOW? Officially called Oval BA, Jupiter's 'Little Red Spot' first appeared in 2000

THE OUTER ANATOMY OF JUPITER

The Great Red Spot might be on the way out, but even without it Jupiter's stripy, stormy surface will remain one of the most dynamic and enthralling planets to look at through a telescope. Here are some fascinating features to look out for...

1 BROWN OVALS

These dark patches are breaks in the upper cloud layers that allow us a rare glimpse at the darker clouds that lurk underneath. These ovals only appear in the north, but the reason why is unclear.

2 DARK ZONES

The darker stripes are low-pressure areas referred to as 'bands', and are usually red or brown in colour, indicating that they are richer in organic compounds than the light zones – possibly because they're closer to the surface. This hypothesis is supported by observations from the Pioneer probe in the 1970s that showed that the darker bands have a higher temperature than the lighter ones.

3 BANDING

Jupiter is divided up into a series of light and dark parallel 'stripes'. These are actually a series of ever-shifting cloud bands that range in colour from yellows and blues to tans and browns. Wind currents stretch around Jupiter's circumference, rather than forming circular patterns as winds do on Earth, due to Jupiter's high rotational speed.

4 LIGHT ZONES

The light areas are regions with high-pressure wind currents. They are thought to be the result of gases – mostly hydrogen and helium, with smaller amounts of ammonia, methane and water vapour – rising up from deep within Jupiter's interior.

5 GREAT RED SPOT

Jupiter's most famous feature isn't always visible from Earth – the planet rotates in just under ten Earth hours, constantly bringing the storm in and out of view. The winds in the storm itself take about six days to rotate. Measurements suggest the spot's clouds are five miles higher than the surrounding clouds.

© NASA

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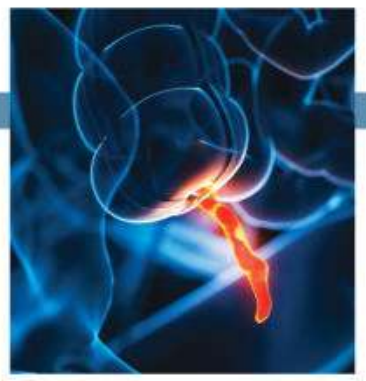
When was the last ice age?

Ian Sanders

There's been a series of ice ages over the past million years or so. Sometimes this whole period is referred to as the 'ice age', even though it has included many individual glacial periods that alternated every hundred thousand years or so, with warm periods called interglacials. More accurately, the last ice age refers to the most recent of these glacial episodes. This global descent into a cold climate started about 100,000 years ago and ended 11,700 years ago.

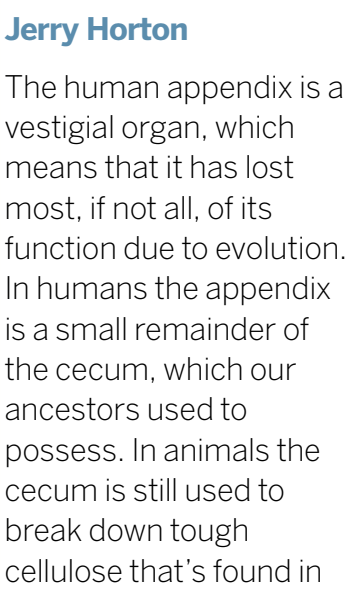
That whole period can be regarded as the last ice age, though it was also complex, with varying climates. The coldest part, when massive glaciers extended as far south as Britain, happened between 25,000 and 20,000 years ago; we call it the last glacial maximum. Past interglacials have been quite variable in length; so far ours has lasted 11,700 years. According to geophysicists, our interglacial still has several thousand years left to run, after which another ice age may well begin. However, human influence could change everything. The climate system is very complex and delicate, and global warming could hugely affect the onset of the next ice age.



WHAT IS AN APPENDIX?

Jerry Horton

The human appendix is a vestigial organ, which means that it has lost most, if not all, of its function due to evolution. In humans the appendix is a small remainder of the cecum, which our ancestors used to possess. In animals the cecum is still used to break down tough cellulose that's found in plants. The appendix is located at the join between the large and small intestines and is a small tube with a closed end. If the open end of the tube becomes blocked, the appendix will swell and must be removed to prevent it from rupturing.



WHY IS SALT BAD FOR THE HEART?

Christopher Attwood

Too much salt is bad for you as it increases the demand on your heart to pump blood around the body. This is because when you eat salt it causes the body to retain water, which increases your blood pressure, and this places more strain on your heart.

Did you know?

An appendectomy is the name for when the appendix is removed

CAN ANY COCKROACHES FLY?

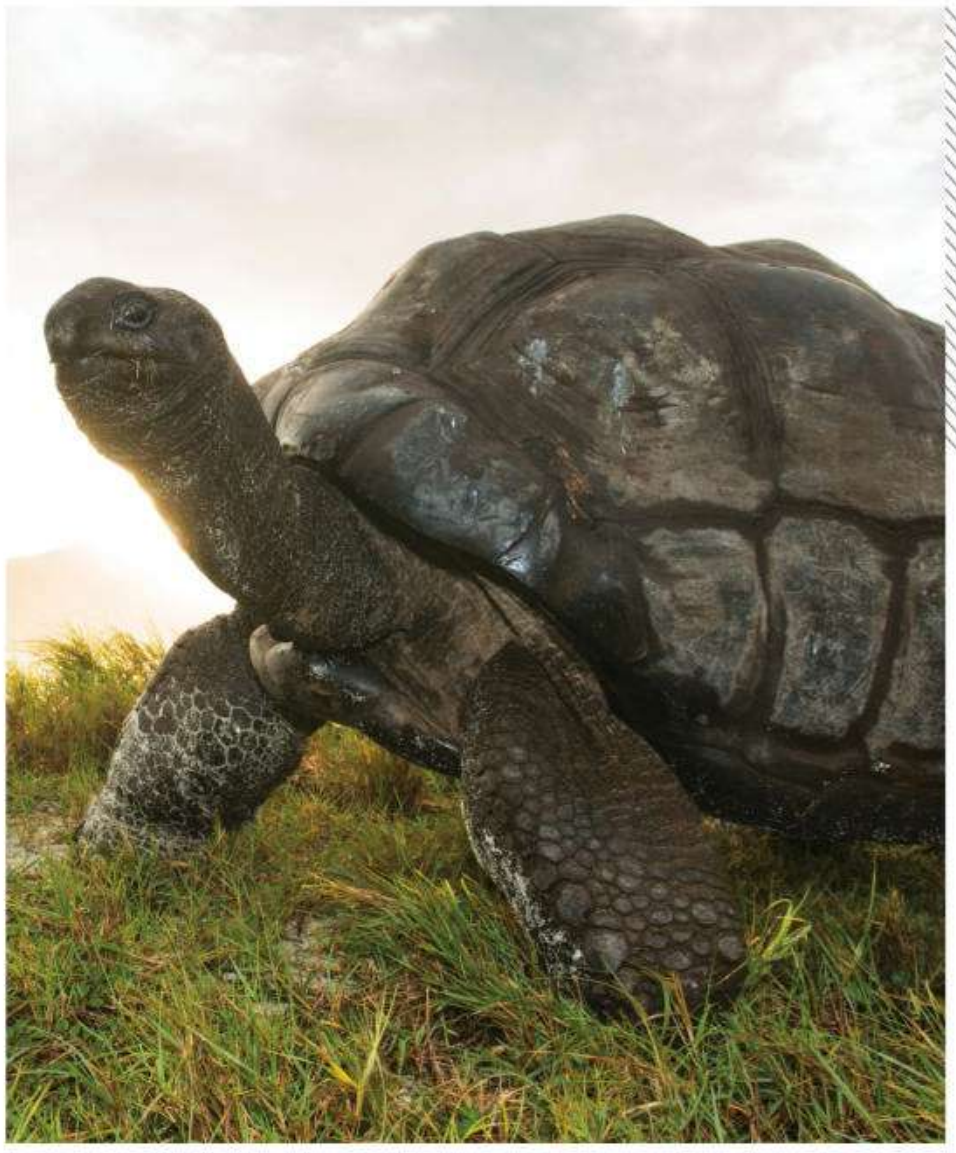
Jonny Osmond

This depends on the species. In the case of the cosmopolitan pest species that breed indoors, like American and German cockroaches, both sexes have well-developed wings and are able to fly. Male oriental cockroaches, however, have wings reduced in length, and the females just have small buds, so neither sex can fly. Some tropical species like the giant hissing cockroach from Madagascar are wingless in both males and females. In Britain we have three species of native cockroach, all of which have well-developed wings and are capable of flight.

HOW DO REWRITABLE CDS WORK?

Ben Swindell

A normal CD has a surface covered in microscopic bumps – a bump will signify a 'zero' and a flat will signify a 'one' in the binary system, and this is how data is read. This has to be different for a rewritable disc though. For this, a dye is used to coat the surface. When writing on the CD, the dye will either be opaque or clear, with the two states representing the binary number system. The dye is designed to change between opaque and clear so the disc can be rewritten several times.



How do tortoises live so long?

Aaron Krazt

Tortoises live so long because they grow at a steady rate and hibernate. Tortoises, like other reptiles, are cold blooded, or ectothermic, so they need to 'warm up' by absorbing heat from their surroundings to keep active. In winter, when food is scarce and the temperature falls, tortoises in the wild stop eating, their breathing and heartbeat both slow and they go into a deep sleep. Studies show that tortoises grow rapidly during their early years and continue to grow at a steady rate that decreases with age. There is evidence of extreme age, although some reports of tortoises living over 150 years have proven unreliable, as has counting the growth rings of shell plates.

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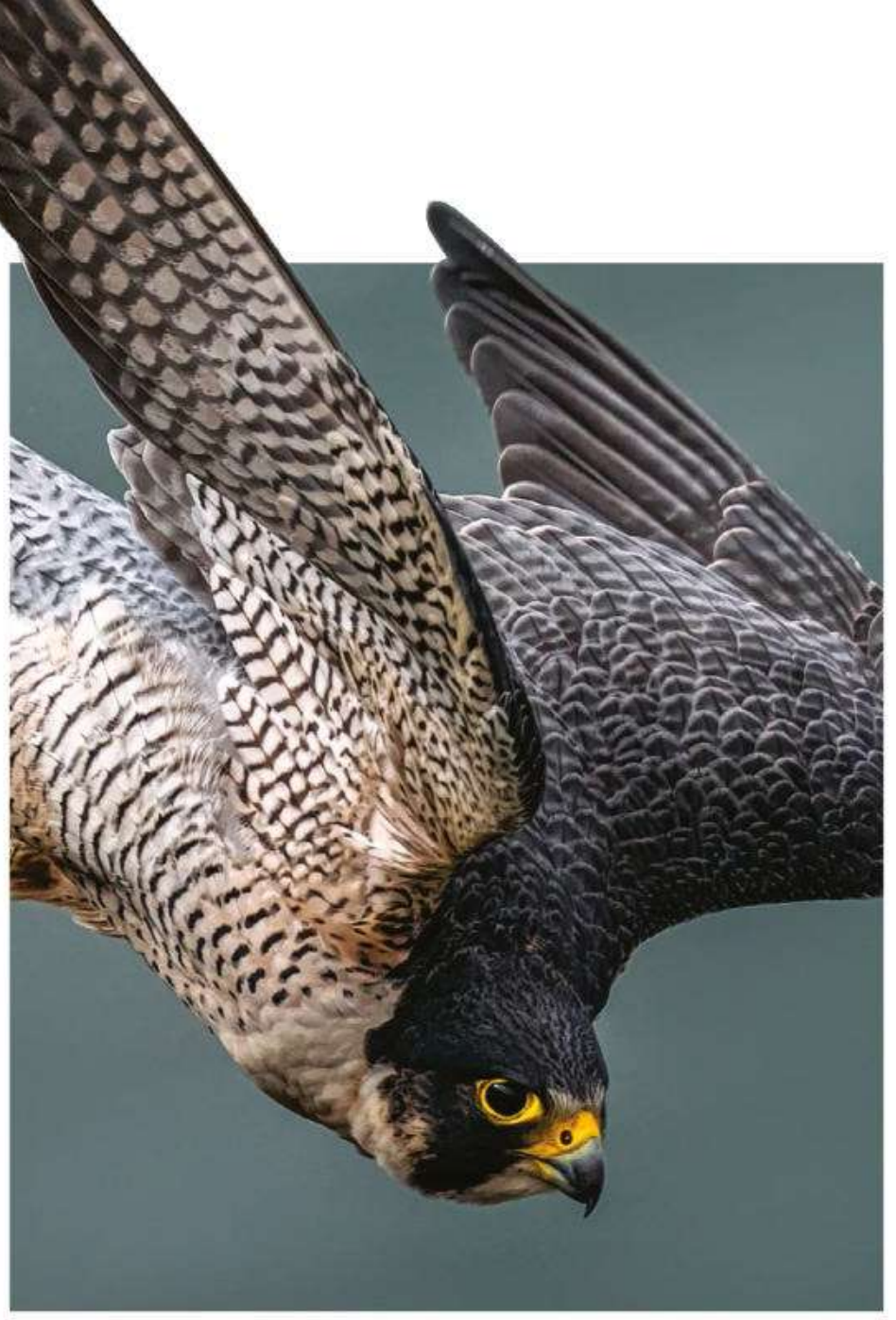

WHAT'S THE FASTEST ANIMAL EVER?

Denny Boele

The fastest animals are birds, as high-speed flight is easier than fast running, and the latter is easier than fast swimming. The absolute champion is the peregrine falcon, which while diving can reach over 186 miles per hour. If you count true flapping flight as opposed to diving, the fastest bird – and animal – is the white-throated needletail, a relative of the chimney swift which is found in the UK. It can fly at about 106 miles per hour.

So what's the big rush all about? Fast flying, running and swimming developed as an adaptation to catching prey or avoiding predators. Swifts fly fast to catch enough insects in the air to fuel their bodies, and their chicks while nesting. Cheetahs, meanwhile, run fast in order to catch speedy gazelles.

What is fog?

@BoreD666

Fog is a condensed collection of water droplets and ice crystals near Earth's surface. Fog is differentiated from clouds through both its height – clouds being significantly higher in the atmosphere – and how moisture has been generated, with the former acquiring it from local ground-based sources such as rivers, oceans and marshes. As a general rule, fog reduces visibility to less than 1,000 metres, while mist or haze is anywhere over that distance. Typically, fog accumulates in low-lying areas of terrain such as valleys and plains, due to the increased moisture content and shelter from strong winds.

WHY DON'T LAKES HAVE TIDES LIKE THE SEA?

Oscar Forum

Lakes do have tides, but they're not usually big enough to see. Tides are changing sea levels mostly caused by the Moon's gravitational pull on Earth. As the Moon draws the sea towards it in one place in the world, the sea moves away from the coast somewhere else. The change in sea level depends on the size and location of the sea, how deep it is and the slope of the ocean floor at the coast. Lakes experience the same gravitational pull, but because they are much smaller than seas, their tides are also smaller and so more difficult to detect.

WHY DOES A WARM TONGUE STICK TO A FROZEN OBJECT?

Nathan Janes

This concerns the transfer of heat from saliva, as heat naturally passes from warmer to colder objects. The saliva on the tongue is warmer than the frozen object. This means that when the tongue touches the object, the saliva on it becomes colder as the heat is transferred. Once the saliva loses its heat, it cannot replace it fast enough to melt the ice, so the saliva freezes, forming new crystal structures with the ice on the frozen surface.

WHAT IS THE WOOLLY BEAR MOTH?

Anna Taylor

It's a moth in the Arctic that was thought to live for 14 years as a larva. The summers there are so short that it can't eat enough food to develop fully, so needs to find a safe place over winter. Over winter the caterpillar freezes, so it's not strictly in hibernation. When it becomes an adult moth it will live for just a few days, or even less, but it's still a remarkable creature.

Did you know?

Gamma radiation is the most harmful to humans

Why is radiation such a hazard?

Paul Donaldson

Radiation is a process in which high-energy particles pass through the air or solid objects. The particles collide with the atoms and molecules in cells along the way. At high levels this can be very dangerous to plants and animals alike. High levels of radiation can damage cells so they begin to multiply rapidly, causing cancer. Radiation naturally occurs in rocks and enters our atmosphere from space. However, this amount of radiation is so small, it's harmless. Radiation can also be useful in medicine, as seen in technology like X-ray machines.

WHAT IS SURFACE TENSION?

James O'Connor

Surface tension is characterised by an increased cohesive force between any liquid's atoms at a surface level. This is because the molecules at the surface of a liquid don't have the same number of molecules surrounding them at all sides like with those deeper in the fluid, leading to them becoming more strongly associated with their immediate neighbours – those also on the surface. As such, this creates a thin film of molecules on top of a liquid that demonstrate an enhanced intermolecular attractive force. Surface tension is typically measured in dynes per centimetre, which describes the necessary force to break a film at a one-centimetre length. The strength needed to break a liquid's film depends on the density and molecular make-up of the fluid – something that can vary depending on its heat. For example, the surface tension of water at 25 degrees Celsius is about 72 dynes per centimetre, while at 100 degrees Celsius this drops to below 60 dynes per centimetre. This is why when you heat oil in a pan it becomes slicker and runnier than when cold, as there's less surface tension in the fluid.

© Getty

Did Marie Antoinette really say "Let them eat cake"?

Asha Dese

Probably one of the most famous myths ever to spread through Western culture, Queen of France Marie Antoinette's sentiment that if French peasants had no bread to eat then they should eat cake instead is at best a misunderstanding and at worst a complete fabrication.

The myth goes that on the verge of the French Revolution of 1789, upon hearing there was a severe bread shortage across the country, Marie said, "S'ils n'ont plus de pain, qu'ils mangent de la brioche," which translates as, "If they have no bread, let them eat cake". At first glance, this appears to be pretty clear-cut. However, there are two elements to this story that are not taken into account. Firstly, laws enacted during Marie's reign forced any baker who ran out of cheap bread to sell their finer produce, such as brioche – actually a sweet bread, at the same rates. This means that Marie's alleged comment would have been stating an already-existing practice. Secondly, the exact same phrase is mentioned in Jean-Jacques Rousseau's *Confessions*, published in 1782, seven years prior to the revolution, so it's likely the words were lifted and linked to Marie.

WHY DOES WATER EXPAND WHEN IT FREEZES?

Matt Lathan

The molecules of most elements are more compact in their solid form than they are in their liquid state, but water is different. As you may know, each water molecule is made up of one oxygen atom with two hydrogen atoms attached. The hydrogen atoms in water have a positive charge and cause the water molecules to be attracted to one another. This attraction forces water to form a net of crystals with lots of gaps in it as it freezes. The crystal net structure takes up more space than liquid water, and so water expands as it turns to ice.

WHAT IS RAM?

Ben Jones

Random access memory (RAM) is a type of physical data storage that can be used to read and write data to so it can be accessed by a computer's central processing unit (CPU). RAM is considerably faster than the hard drive memory used to store files, and as such allows data to be processed more efficiently. Importantly, unlike hard drive memory, RAM is volatile and does not retain information after power is cut to the machine, resetting for future usage.

WHAT IS ABSOLUTE ZERO?

Dan Castle

Absolute zero is equal to -273 degrees Celsius. Nothing can ever be colder than absolute zero, just as it is impossible to have less than no thickness. The colder something is, the harder it is to cool it any further. This is the bottom of the scientific temperature scale, or zero degrees Kelvin. This way of measuring temperature is named after Lord William Kelvin, who devised the theory behind the unit in the middle of the 19th century.

IS THE MOON BELOW, IN OR ABOVE EARTH'S EXOSPHERE?

Jimsy Brown

At its closest point of orbit, the Moon is 225,700 miles from Earth, while at its furthest point it is over 238,900 miles away. The exosphere is the uppermost layer of Earth's atmosphere and marks a transitional zone between the atmosphere's lower layers and interplanetary space. The exosphere is comprised of various light gases, including hydrogen, helium, carbon dioxide and atomic oxygen.

At its lowest point, which lies at the upper boundary of the thermosphere and is referred to as the exobase, the exosphere is about 300 miles above the terrestrial surface of Earth. The beginning of the exosphere varies, however, and no fixed point can be demarked, leading to the exosphere being roughly characterised by a reading of negligible atomic particle collisions, which reduce continuously the further the exosphere extends into space.

At the exosphere's upper boundary – which is technically theoretical – its altitude above our planet is approximately 120,000 miles, which is roughly half the distance to the Moon. As such, regardless of where the Moon is in its orbit of Earth, it always lies outside and above our planet's exosphere.

WHY DOES MY STOMACH RUMBLE WHEN I'M HUNGRY?

Peter Bettings

The origin of stomach rumblings comes from muscle contractions and fluctuation. As food enters the gastrointestinal tract, its walls squeeze the contents through the system at regular intervals to clear any potential buildup of food, gases and liquids. This fluctuation is known as the basic electrical rhythm. The speed and force of the muscle fluctuations increases both in the presence of foodstuffs and also without them. In this latter case, the nerve receptors initiate a reflex generation of electrical activity, causing the muscles to contract and vibrate – or rumble.

Did you know?

Ryegrass is the most common type in the UK

Which type of grass is most used in lawns?

Margaret Arde

Whether created by laying turf or by sowing seed, lawns consist of a mix of grass species, and the ideal blend depends on the location and the lawn's intended use. Heavily used lawns will contain a high proportion of tough perennial ryegrass, which can withstand frequent trampling. In contrast, lawns with a high percentage of fescues have a finer, more ornamental look and are tolerant of shade but cannot be heavily used. Finally, species like Kentucky bluegrass are used to improve a lawn's drought tolerance.

© Getty

BRAINDUMP

CAN ENERGY BE DESTROYED?

Naseem Ali

The law of conservation of energy states that energy cannot be created nor destroyed, only transferred from one form to another. Energy can exist in different forms, such as thermal (heat), kinetic (movement) and potential (stored). Not all energy is transferred to 'useful' forms of energy though – for example, when you run, some of the chemical potential energy you use from food is 'lost' as heat and sound. According to some scientists, all energy and mass were created when the universe was born in the Big Bang nearly 14 billion years ago, and energy can be converted into mass, and vice versa.

Why do we stop growing?

Keith Graves

We stop growing because we're genetically programmed to. Our genes, from our parents, determine how we develop, but environmental factors also affect how tall we grow. We know our DNA controls the growing process, but scientists are still unsure how our genes do this. We stop growing when we reach the age at which our bodies can reproduce. At this point, the purpose for growth is complete, so our genetic control centre tells us to stop.

WHY DO WE GAIN AND LOSE WEIGHT?

Paul Whitting

Humans use the energy in food to live; this energy is measured in calories. If people consume lots of calories from food and don't burn them up, they get converted to fat and stored in the body, and so people gain weight. This was very important when humans were not always guaranteed access to food daily. They could use the stored fat in their bodies for energy until they could find food again. If people burn more calories than they consume through food, by doing lots of exercise and so on, then their bodies use the fat stores instead, and as a result they lose weight.

HOW QUICKLY DOES HUMAN HAIR GROW?

Phillip House

Human hair grows on average 1.25 centimetres per month, which is equivalent to about 15 centimetres per year. There are several variables that can affect hair's growth rate, such as age, health and genetics. Each hair grows in three stages, the first being the anagen phase, where most growth occurs. The longer your hair remains in this stage dictates how long and quickly it develops; this can last between two and eight years and is followed by the catagen (transitional) and telogen (resting) phases. Hair growth varies across different areas of the head, with that on the crown growing the fastest.

Did you know?

The farthest known object is a galaxy 13.5 billion light years away

How big is the universe?

Norm Bale

To answer this, we can make estimates based on the expected age of the universe and the motion of galaxies. The universe itself is expanding, but not in the way a balloon does. The expansion is taking place throughout the universe, where space-time itself is being stretched outwards. Whereas a balloon pushes its edges out as it expands, the universe is also pushing its insides outwards, but with no centre to the universe, everything is moving away from everything else. It's a bit like baking a ball of dough – the entire dough grows, not just its edges. However, based on our knowledge of how old the universe is – roughly 14 billion years – we can observe a theoretical 'edge' of the visible universe about 14 billion light years away from us. This is the furthest distance we can see, as light that might be further has not had time to reach us yet. Thus we can say that the visible universe has a diameter of 28 billion light years, 14 billion light years in either direction from Earth. However, what's beyond this is unknown. The visible universe that we can observe could be just a tiny fraction of a much larger universe, or perhaps just one in a system.

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THE LIBRARY

The latest book releases for curious minds

HOW TO EXPLAIN CODING TO A GROWN-UP

A GUIDE TO GETTING PARENTS UP TO SPEED

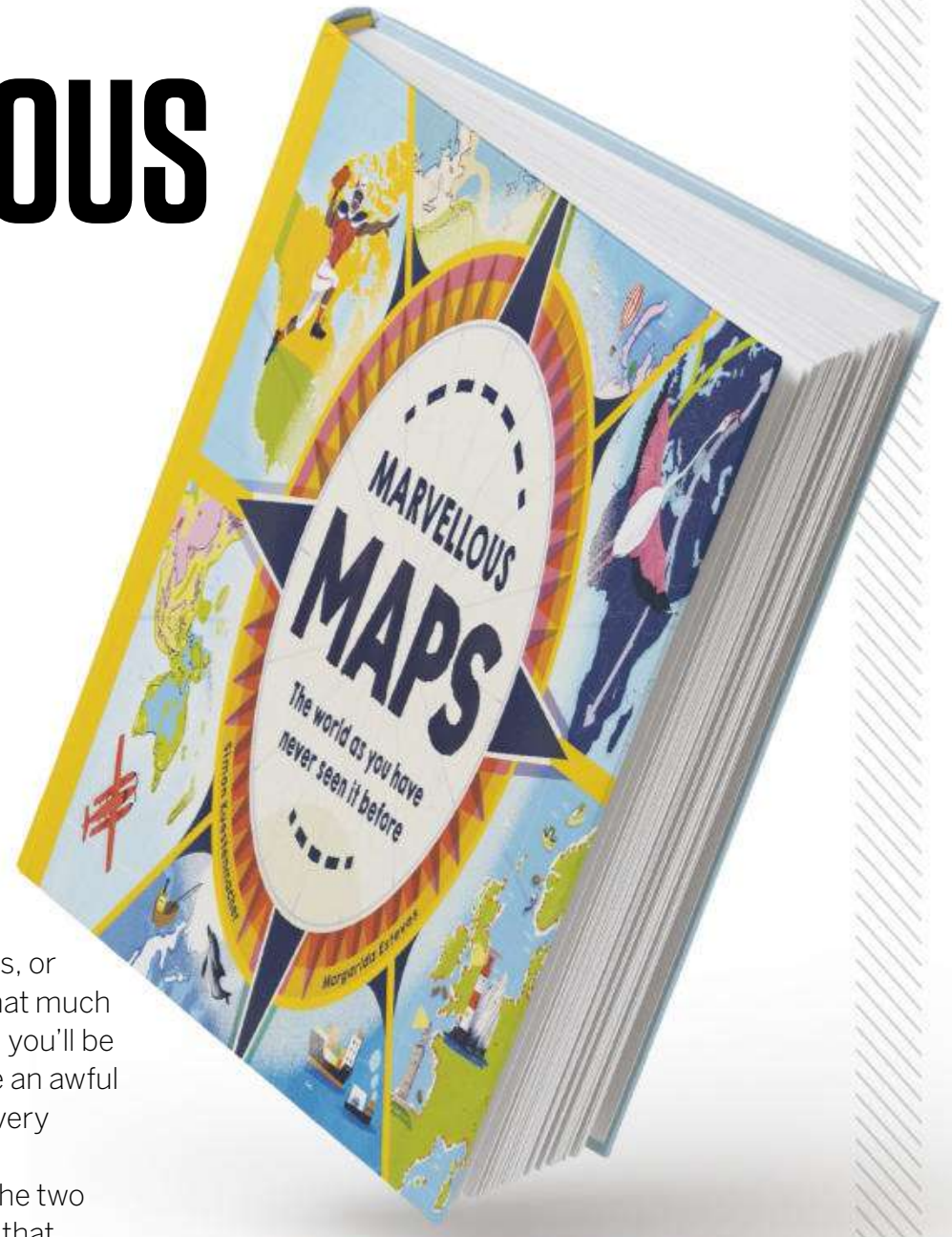
AUTHOR **RUTH SPIRO**
ILLUSTRATOR **TERESA MARTINEZ**
PUBLISHER **CHARLESBRIDGE**
PRICE **£16.99 / $17.99**
RELEASE **10 OCTOBER**

This is a parenting book in reverse, teaching your children how to talk to you about the complicated subject of coding. *How to Explain Coding to a Grown-Up* is a witty, fresh take on the typical children's book, teaching its young readers about coding while simultaneously helping them talk about the subject with adults. It's not short on humour – especially the 'pro-tips' on how to keep your parents fed and happy while trying to teach them about algorithms. Using playgrounds and street crossings as examples relating to the world of coding, this book simplifies complex computer science for the entire family to understand. *How to Explain Coding to a Grown-Up* is brilliantly illustrated, not only artistically, but also because it includes fun and simple diagrams to demonstrate the functions of coding.

MARVELLOUS MAPS

PREPARE TO EXPLORE OUR WORLD AS YOU'VE NEVER SEEN IT BEFORE

AUTHOR **SIMON KUESTENMACHER**
ILLUSTRATOR **MARGARIDA ESTEVES**
PUBLISHER **WELBECK**
PRICE **£20 / $24.65**
RELEASE **OUT NOW**



Maybe you like looking at maps, or maybe you've never given that much thought to them. Either way, you'll be a fan of this book – there are an awful lot of cartographical stats packed into every illustrated map inside that makes it very satisfying to look at. Take, for example, the two maps that show isochrones, or the lines that show how far you can travel from any given destination. *Marvellous Maps* has redrawn a modern isochrone map next to the original isochrone from 1914 that shows at a single glance how long it would have taken someone travelling by ship, train or airship from London to anywhere in the world – be it Eastern Europe, Australia or the heart of Africa. In the case of the latter destination, it took well over a month a hundred years ago compared to under two days of travel time today.

Maps can be both informative and fun. This is exactly what author Simon Kuestenmacher and illustrator Margarida Esteves want the reader to celebrate with them, and it's undoubtedly an engaging book to pore through. There are curious maps, like where various cat and dog breeds come from, and silly maps, like how the world looks like a cat playing with Australia. More informative maps include where the lighthouses of Europe are or the journey of Marco Polo, and the 'questions that you never knew you needed answers to' maps like, 'What's bigger, Pluto or Australia?' and 'Are you closer to London or Paris?' - our personal favourite map type in *Marvellous Maps*. It seems that the nearer the end of the book you get, the more out-of-the-box these maps get. Some wildly lateral thinking must have gone into producing some of them, as if whoever came up with the original concept envisaged how the map would look first before matching the data to it. They really need to be seen to be properly understood.

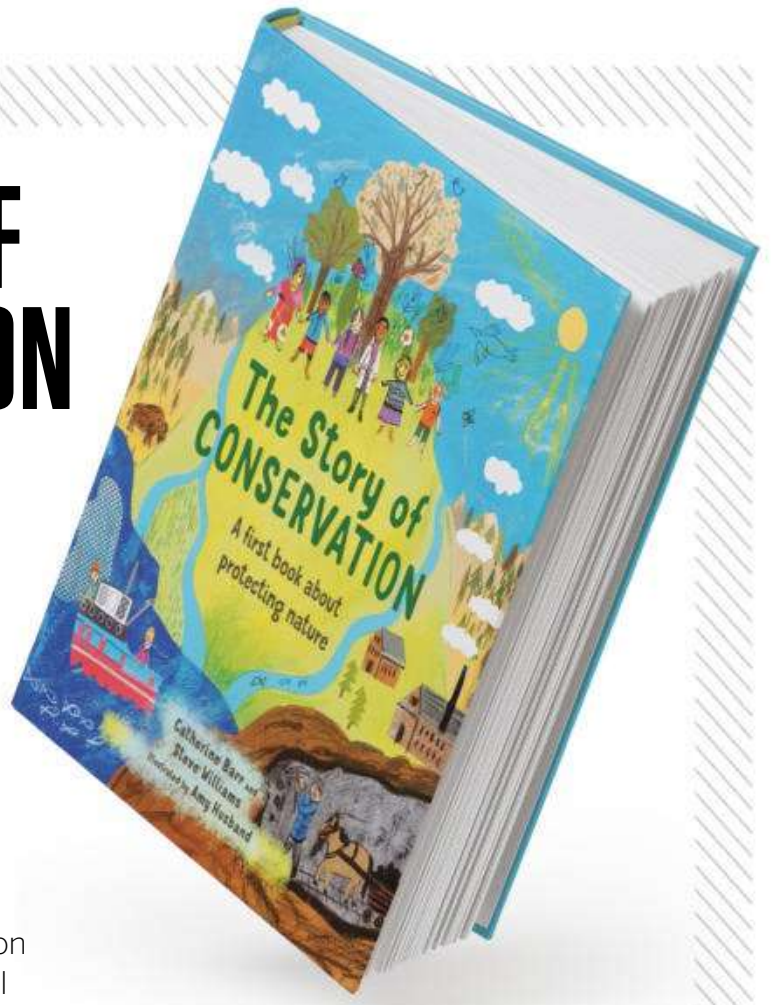
"Maps can be both informative and fun"

Absolutely a book for fans of cartography and interesting ways of interpreting information, *Marvellous Maps* will also entertain anyone who's spent even a small amount of time scrolling and zooming in on Google Earth. It's genuinely fascinating and fun, if not useful.

THE STORY OF CONSERVATION

A FIRST BOOK ABOUT PROTECTING NATURE

AUTHORS **CATHERINE BARR AND STEVE WILLIAMS**
ILLUSTRATOR **AMY HUSBAND**
PUBLISHER **FRANCES LINCOLN**
PRICE **£12.99 / $19.99**
RELEASE **3 AUGUST**

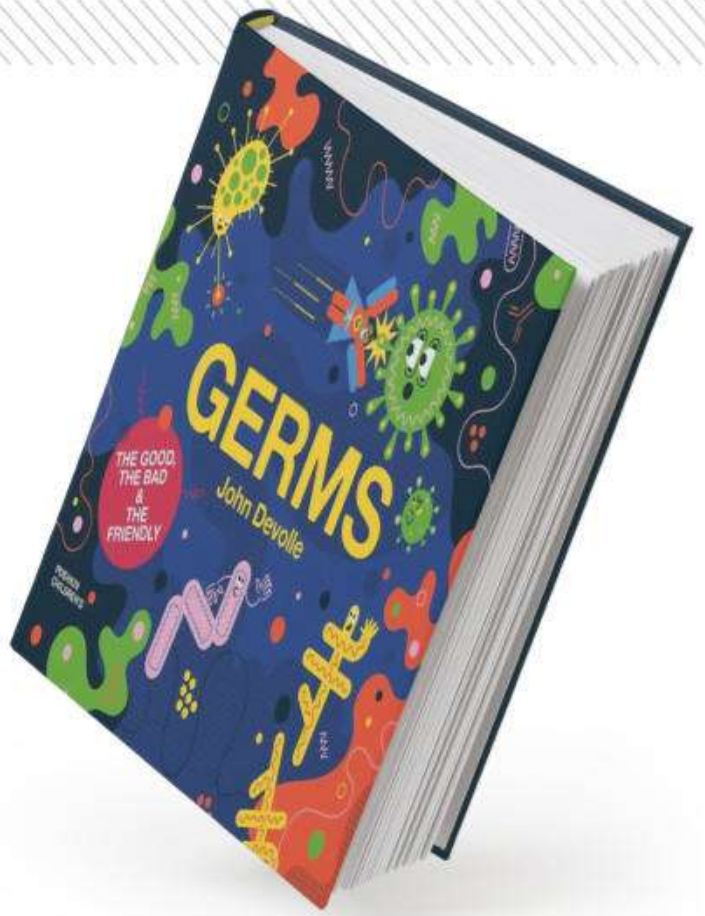


If you're looking for a way to introduce your child to the concept of conversation and discuss some of the environmental issues facing our planet, *The Story of Conservation* is a good starting point. From early civilisations to the modern era, this book takes its readers on a journey through time, highlighting the ways humans have negatively impacted the environment and the steps that are both being taken and need to be taken in the future to reverse human impact and conserve wildlife. This is by no means a facts and stats-laden book, but it provides enough information to ignite curiosity and further questions from its young readers. Each page is filled with wonderful illustrations that provide some levity to an otherwise serious subject.

GERMS

BIG PATHOGEN SCIENCE FOR LITTLE MINDS

AUTHOR AND ILLUSTRATOR
JOHN DEVOLLE
PUBLISHER **PUSHKIN CHILDREN'S BOOKS**
PRICE **£12.99/ $16.95**
RELEASE **OUT NOW**



This book is the perfect introduction to the world of germs for young children. What makes your throat sore or your nose runny? From infection-causing viruses to the fungus that's used as medicine and flavour-enhancing bacteria on foods, readers will meet new microorganisms on each page. As well as educating children about the dangers of disease, the lively illustrations help to reduce feelings of fear towards invisible germs and better understand the tiny organisms that live inside our bodies.

As the author and illustrator, John Devolle expertly targets young minds by providing an engaging narrative and humorous artwork. The bold colours of every illustration highlight the mass presence of germs, in perfect contrast to their usual state as invisible intruders. Complex biological processes are presented simply and personified as characters like superheroes, so a young reader discovering different molecules for the first time can quickly grasp their core roles. By the end of *Germs*, children should have a better understanding of germs and learn how scientists' knowledge of these pathogens has improved through history, too, helping provide our bodies with an effective defence.

THE BOOK OF TIME

ADVENTURES IN THE PAST, PRESENT, FUTURE AND BEYOND

AUTHOR **CLIVE GIFFORD**
ILLUSTRATOR **TEO GEORGIEV**
PUBLISHER **AURUM PRESS**
PRICE **£14.99/ $24.99**
RELEASE **31 AUGUST**

Time is precious, regimented and always passing – but what is time, and how has it been measured throughout history? Covering time in space, on Earth and across the world map, *The Book of Time* is sure to answer any questions you hold about the concept. Providing content for astronomy fans, history lovers and animal enthusiasts, it proves that time impacts absolutely everything. Did you know that, on average, a person spends 33 years of their life in bed? Or that over 1.4 billion years ago a day was five hours shorter than today? Seconds, minutes and hours are all human-devised units, but the incredible statistics packed into this book demonstrate how necessary and insightful the tracking of time can be.

Realistic illustrations on every page transport your imagination to different settings and points in history to display how culture, time-tracking technologies and landscapes are influenced by the concept of time. *The Book of Time* combines timelines of time itself, informative scientific diagrams and animated character illustrations, ensuring that you'll want to spend much of your own time exploring each fact, statistic and revelation.

BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

6			3			4	8	
	4		6	7		5	2	9
8			5	4				1
7	1	9				3	4	
4	3			1		2		
2	5			9		1	7	6
5		1						3
3	8	4	7		6			
						8	5	4

MEDIUM

			9		5			6
5	4		2	1				
2	1	6			7	4	9	
			1			8	5	
	7						2	
	9	5	3		4			
		4		8	2		7	
	6					5	4	
7	3					6		9

HARD

						9	7	
		6		8	9			
			1	7			5	
6			2		7		9	
						2		
2		3				8		7
	3			2		6		9
7	5			1	4			
1								

Word search

Find the following words

FLIES
DIALYSIS
FORMULA
GRAVITY
GALILEO
RECYCLE
POLICE
ASPHALT
MOON
POOP
RAIN
FORCE

S	E	I	L	F	O	D	A	S	H	P	A	L	F	T
R	E	G	Y	F	O	R	C	E	A	I	N	T	O	B
S	X	Y	C	X	E	L	C	Y	C	E	R	P	R	Z
F	O	O	R	M	P	U	M	J	O	M	A	I	M	L
L	U	L	A	G	R	O	K	C	O	N	L	I	U	E
P	A	E	D	L	I	C	O	I	B	O	U	Y	L	F
O	O	P	N	I	R	A	R	P	S	O	W	T	A	M
L	F	O	R	M	A	U	L	P	O	M	N	I	C	V
I	L	D	I	A	I	L	Y	S	I	S	K	Y	O	X
C	I	S	M	I	N	O	Y	C	R	A	Y	N	E	O
E	S	H	R	E	C	Y	T	S	I	O	N	F	L	I
N	E	M	U	L	A	O	O	N	I	O	M	Y	I	L
R	L	E	W	O	G	R	A	V	Y	S	E	M	L	O
A	S	P	H	A	L	T	Y	T	I	N	A	Y	A	C
K	O	G	R	A	V	I	T	Y	Z	E	L	D	G	X

What is it?

Hint:

Treat yourself at the fair

A

Spot the difference

See if you can find all six changes between the images below

Answers

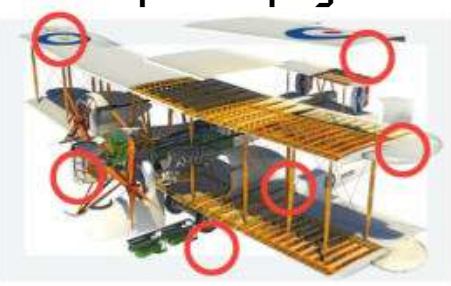
Find the solutions to last issue's puzzle pages

Q1 120 ZETTABYTES
Q2 55 PER CENT
Q3 FOSSIL FUELS
Q4 JUPITER
Q5 186 MILES PER HOUR
Q6 PUMICE

What is it?

TOMATO

Spot the difference



QUICKFIRE QUESTIONS

Q1 What type of galaxy is the Milky Way?

- Spiral
- Elliptical
- Peculiar
- Irregular

Q2 What substance makes up a rhino's horn?

- Ivory
- Bone
- Wood
- Keratin

Q3 What are the teeth at the back of your mouth called?

- Canine
- Molar
- Incisor
- Deciduous

Q4 Which of these metals is not magnetic?

- Nickel
- Iron
- Cobalt
- Copper

Q5 Approximately how long ago did work start on China's Great Wall?

- 700 years ago
- 1,700 years ago
- 2,700 years ago
- 3,7000 years ago

Q6 Which vitamin is potato particularly rich in?

- A
- B
- C
- D

© Getty

HOW TO...

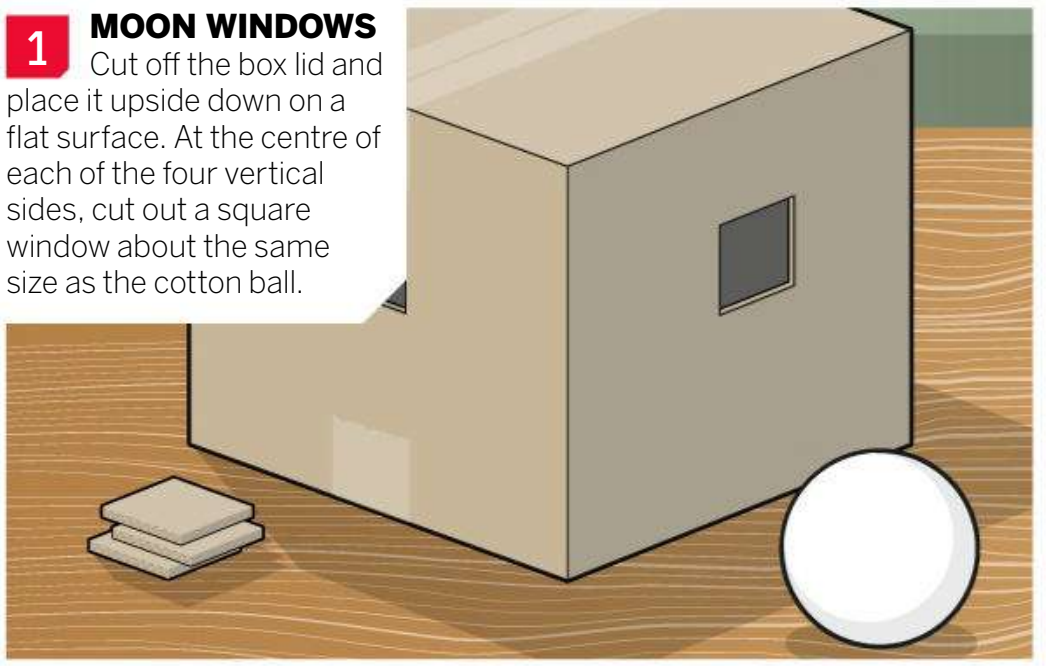
Practical projects to try at home

RECREATE THE MOON'S PHASES

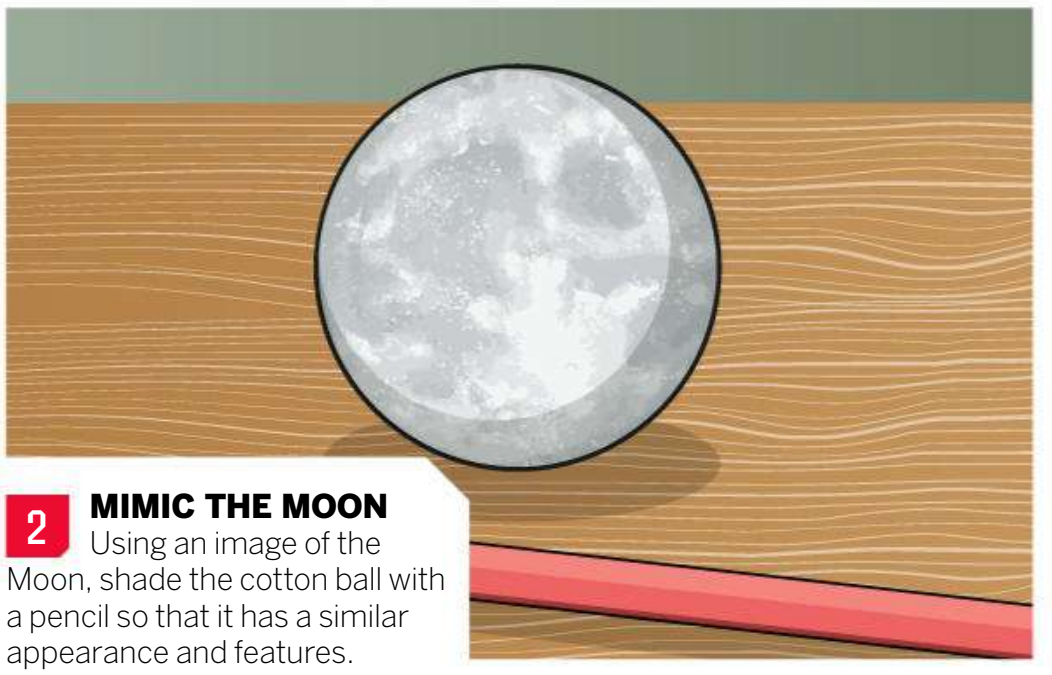
Build this Moon in a box to visually explore the lunar phases

KIT LIST

- One square cardboard box
- One torch or lamp
- One large white spun cotton ball
- One paperclip
- Pencil
- Sewing thread
- Knife
- Tape
- Coloured paper and other decorative materials (optional)



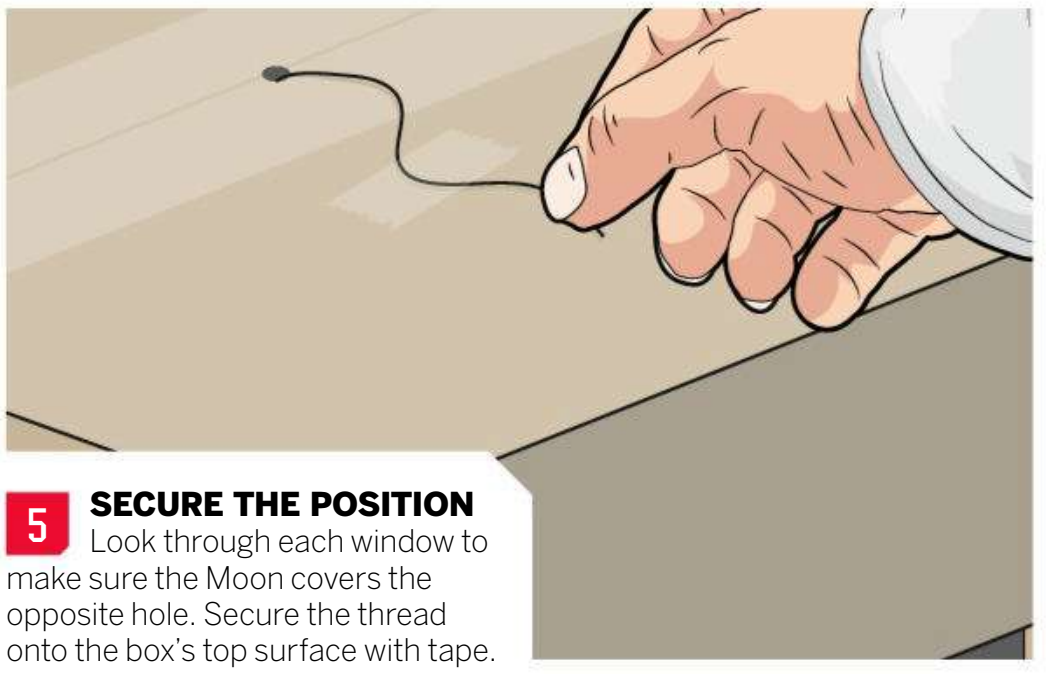
1 MOON WINDOWS
Cut off the box lid and place it upside down on a flat surface. At the centre of each of the four vertical sides, cut out a square window about the same size as the cotton ball.



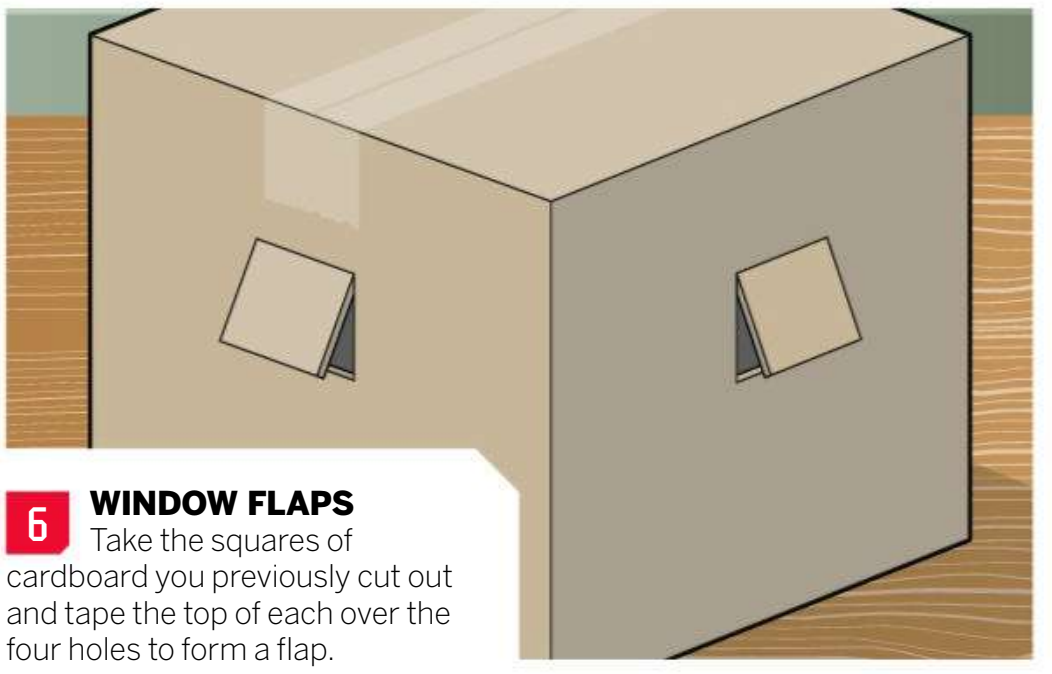
2 MIMIC THE MOON
Using an image of the Moon, shade the cotton ball with a pencil so that it has a similar appearance and features.

3 ATTACH THE THREAD
Push a paperclip into the centre of the spun cotton ball, but make sure about one quarter of the paperclip remains visible. Tie one end of the thread around the paperclip.

4 SUSPENDED SATELLITE
Make a small hole in the centre of the top of the box, then thread the other end of the thread through the hole so that the Moon hangs in line with each of the four windows.



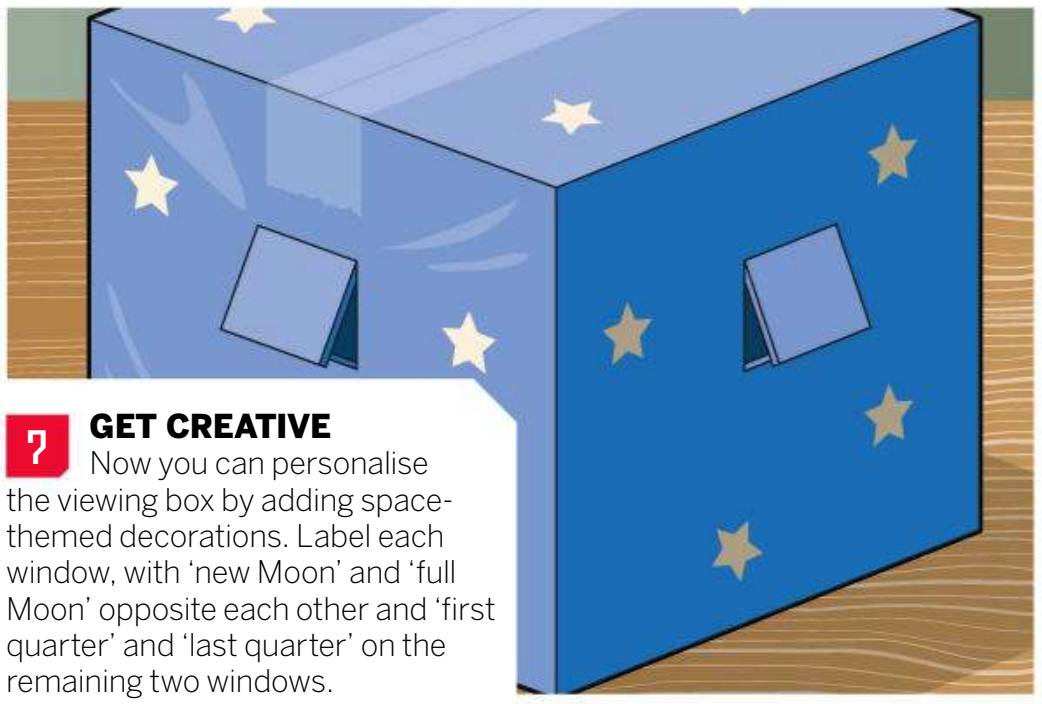
5 SECURE THE POSITION
Look through each window to make sure the Moon covers the opposite hole. Secure the thread onto the box's top surface with tape.



6 WINDOW FLAPS
Take the squares of cardboard you previously cut out and tape the top of each over the four holes to form a flap.

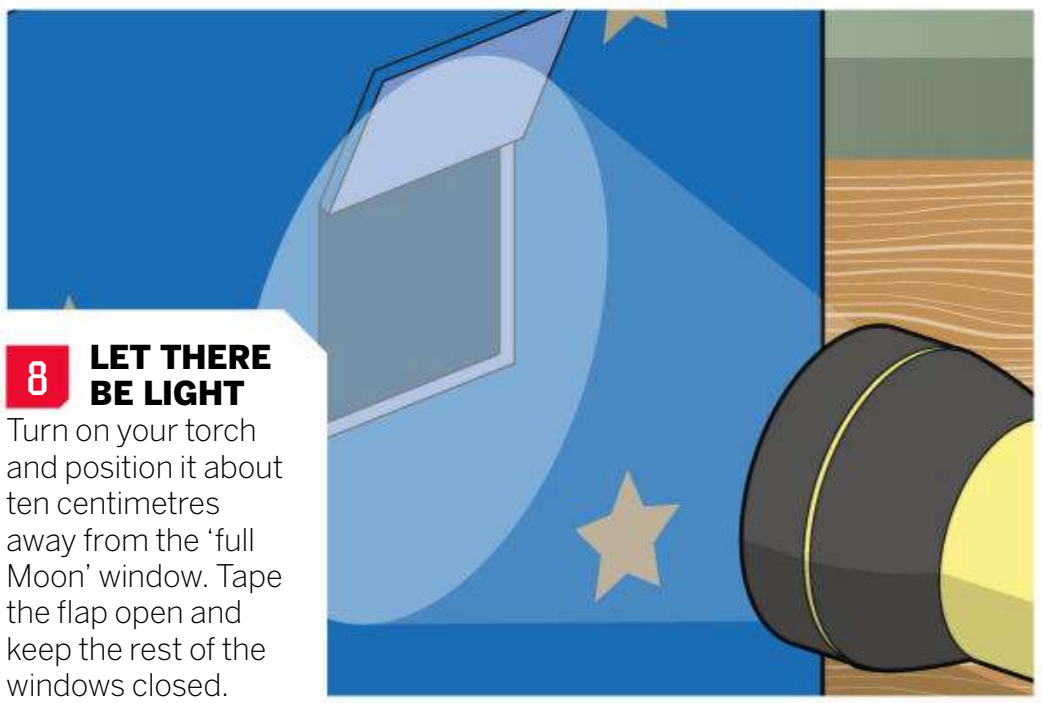
DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you



7 GET CREATIVE

Now you can personalise the viewing box by adding space-themed decorations. Label each window, with 'new Moon' and 'full Moon' opposite each other and 'first quarter' and 'last quarter' on the remaining two windows.



8 LET THERE BE LIGHT

Turn on your torch and position it about ten centimetres away from the 'full Moon' window. Tape the flap open and keep the rest of the windows closed.

9 OBSERVE THE MOON

Switch all lights off so that the torch is the only light. As you peer into each of the windows, take note of how the angle of the lighting impacts each stage's appearance.

SUMMARY

In this model, the spun cotton ball is the Moon and the torch's light represents the Sun. The model shows how the Moon itself, although appearing bright, does not emit its own light. Instead it reflects light from the Sun as it orbits Earth. At different stages of its orbit around Earth, we see the Moon reflecting more or less light. It takes the Moon 29.5 days to orbit once around our planet. At the first and last quarter of its orbit, half of the Moon appears lit. This is just how it appears from our position on Earth, as in reality only half of the Moon receives sunlight at any time. We are just seeing half the lit-up part during this stage. It's worth noting that while this model shows the Sun directly behind the Moon during each new Moon stage, this only happens two to five times in a year. Earth is also moving around the Sun while the Moon moves around Earth, meaning this alignment can't occur every time.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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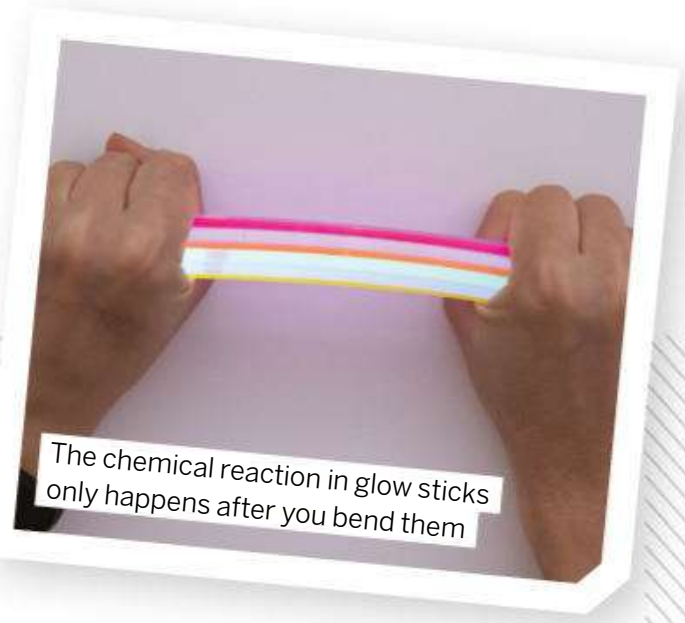
INBOX
Speak your mind


The chemical reaction in glow sticks only happens after you bend them

LETTER ABOUT LUMINESCENCE

Dear **HIW**,
I was told that glow sticks are toxic and I would like to know if this is true? What's inside them and how does luminescence suddenly appear when you crack them?
Zara Bowen

Glow sticks can be a fun addition to any party and are generally safe as long as the contents remain inside. You shouldn't cut open a glow stick, as the chemicals inside can irritate the skin. Usually, the chemicals inside aren't toxic, but they also aren't edible and should be kept away from the skin and eyes. When you crack a glow stick, you're actually breaking a thin glass vial inside the stick. This releases the chemical hydrogen peroxide and an acidic substance called phthalic ester into the plastic cylinder. This highlights another reason to avoid cutting open glow sticks, as small shards of glass penetrate the plastic cylinders if you cut or snap them apart.

The remaining chemicals are outside the glass vial before the glow stick is activated. As the chemicals mix, they react to become luminescent. It's the hydrogen peroxide reacting with phenyl oxalate ester that creates the glow. As they react, energy is emitted that excites the surrounding dye and produces light. The hydrogen peroxide inside the small sticks is stronger than it is in other products. Hydrogen peroxide is also used as a cleaning agent and is sold in hair dyes and oral hygiene products. It can burn the mouth, throat, skin and eyes if it's spilled or swallowed. The best way to reduce this irritation is to rinse with water immediately. While they are a mesmerising addition to celebrations and are generally safe, you should use them with caution and make sure children and pets are supervised at all times.

LETTER of the MONTH

TACKLING TEETH

Dear **HIW**,
What did people use before toothpaste was invented and how did the invention come about?
Samie Kakkar

Toothpaste cleans your teeth and leaves you with a minty freshness. This feeling of having clean teeth is something that ancient human civilisations strived for before toothpaste was invented. For example, ancient Egyptians would fray the end of a twig to serve as a makeshift toothbrush, while people in China in 1600 BCE used sticks from aromatic trees to prevent bad breath. Some materials used around the world instead of toothpaste were abrasive, like salt, burned eggshells and charcoal, but when rubbed on the teeth they brush and scrape away plaque.

The first toothpaste that was similar to what we use today emerged in the 1850s. Using a ready-made paste with mint extracts, 'tooth creme' was much easier to apply than the previously used powders.

Menthol in toothpaste creates the cool sensation in your mouth

WIN!
AN AMAZING PRIZE FOR LETTER OF THE MONTH
MARVELLOUS MAPS
Discover the world as you have never seen it before

ITCHY BITES

Dear **HIW**,
Why are fly bites so itchy? And why don't you notice them until after you have been bitten?
Tyler Ellis

Insect bites can leave an itchy rash on the skin for a few days. This is an allergic reaction to the saliva of the insect. Your body launches an immune response to the area of skin that was targeted. This involves a release of fluid to wash out foreign proteins in the saliva, inducing swelling, while an increase in histamines repeatedly activates the nerve cells at the site to provide an itchy sensation. You won't feel this right after a bite because a fly's saliva has anaesthetic properties to keep its victim blissfully unaware that it's being bitten until the fly is long gone.

Swelling from fly bites can be small or golf-ball sized

NEXT ISSUE
ISSUE 180
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Ducks can lose their feathers in a natural process called moulting

SPOTTING BIRD FLU

Dear **HIW**,
Some of the ducks near where I live seem to have lost many of the feathers on their heads. Is this a sign of bird flu or something else?
Kristyna Svoboda

This is an interesting observation. Although ducks generally don't show signs of contracting bird flu compared to other birds, it can impact the appearance of their heads. This is more likely to be in the form of swelling and discolouration. Some other reasons why the ducks you saw may have lost some feathers include hormone changes in mother ducks and stress. For male mallard ducks, they will lose the bright-coloured feathers on their heads to achieve better camouflage when they no longer need to attract a mate.

Books can smell musty or earthy

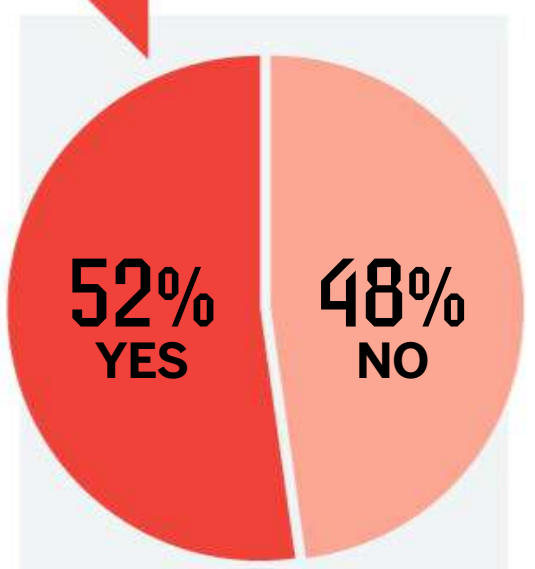
BREATHING IN BOOKS

Dear **HIW**,
I sometimes buy old books that have a musty smell. Is this caused by mould and is it harmful when breathed in?
Stephen

Books have a range of smells, depending on which chemicals are used in their manufacture. In their glue, paper and ink, different chemical compounds break down over time, releasing new compounds in the process. Lignin, for example, which is present in wood-based paper, produces a vanilla-like scent as it breaks down, while cellulose creates that familiar musty smell. Generally, smelling old books isn't bad for you. However, very old books contain harmful spores of mould and bacteria, so it's wise to fumigate these.

WE ASKED YOU

This month on social media, we asked you: Should humans colonise the Moon?



@MAX.FX.SHORTS

Ideal lifestyle for those who want to get away from the city

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Fix Earth before destroying other planets

@DEFINITELY.NOTMAX

Great view of Earth

@HAMID.BAGHERNIA

It will be in constant supply need from Earth and it's the biggest issue

@DOODLENEWS

I don't think we know enough about the Moon

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HOW IT WORKS

Future PLC Quay House, The Ambury, Bath, BA1 1UA

Editorial
Editor **Ben Biggs**
Senior Art Editor **Duncan Crook**
Production Editor **Nikole Robinson**
Senior Staff Writer **Scott Dutfield**
Staff Writer **Ailsa Harvey**
Group Editor-in-Chief **Tim Williamson**

Contributors
Andrew May, Mark Smith, Tereza Pultarova, Andrew Jones, Sascha Pare, HArry Baker, Joanna Thompson, Nicoletta Lanese, Hannah Osborne, Jennifer Nalewicki, Brandon Specktor, Ethan Freedman

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Photography
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Advertising
Media packs are available on request
Account Manager **Hayley Brailey-Woolfson**
hayley.braileywoolfson@futurenet.com
07934 357861
Advertising Sales Director **Lara Jaggon**
lara.jaggon@futurenet.com
07515 961911

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Circulation
Head of Newstrade **Tim Mathers**

Production
Head of Production **Mark Constance**
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SVP Lifestyle, Knowledge and News **Sophie Wybrew-Bond**

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Tel +44 (0)1225 442 244

FAST FACTS

Amazing trivia that will blow your mind

900 KILOGRAMS

The volcanoes on Jupiter's moon Io spew nearly a tonne of gas into space every second

195

There are just under 200 recognised countries

WHALE POO OFFSETS CARBON IN THE ATMOSPHERE

41%

The world's most common mineral, feldspar, makes up around half of Earth's crust

Fungi are neither animals nor plants; they're in a kingdom of their own

SIX MINUTES

The brain takes very little time to react to alcohol

50%

Nearly half of all museum specimens are incorrectly labelled

TWO

Marie Curie won a Nobel prize for both Physics and Chemistry

330 BCE

The word 'technologia', or technology, was first coined by Aristotle over 2,000 years ago

71%

Nearly three-quarters of Earth is covered in water

HUMANS ARE THE ONLY ANIMALS THAT HAVE CHINS

© Getty

Advertisement

Car, home and travel insurance plus broadband, breakdown cover and more. Get more info or compare quotes, for over 40 products, at go.compare

Made from plastic waste at risk of polluting the ocean

The new **Sistema® Ocean Bound Plastic collection** is perfect for transporting your lunches and drinks to and from school. The range includes two bottles and three snack and lunch boxes.

It is durable and versatile meaning it can withstand wear, pressure or damage, and fits perfectly into your school backpack. It can be reused, helping to cut down the number of single-use plastic containers and bottles thanks to its environmentally friendly design.

What is Ocean Bound Plastic?

Generated within a 50km radius of coast lines[1], ocean bound plastic refers to plastic waste that has been incorrectly disposed of on land, shores, waterways and river areas, which poses a risk of polluting the ocean. It is currently estimated that ocean bound plastic generates 80% of plastic marine litter.[2] Plastic waste that is thrown away correctly in landfills or organised dump sites is not categorised as ocean bound.

To learn more, visit:
www.sistemaplastics.com/uk/sustainability

Made using up to 35% of recycled plastic found in the ocean.

Food-safe & BPA free

Made using up to 50% of recycled plastic found in the ocean

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